EFFECTIVENESS OF PROBLEM-BASED LEARNING ON IMAGE CRITIQUE SKILLS IN A SECOND-YEAR CLINICAL RADIOGRAPHY COURSE: A CASE STUDY

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To my family,

For their endless love and support!

Love you all!

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Numerous studies have been conducted to examine the effectiveness of problem-based learning (PBL) in higher education programs that prepare health professionals for their clinical careers, such as undergraduate nursing programs. Even though undergraduate nursing education and radiography education have similarities, studies that focus on the effectiveness of PBL in radiography have not been documented in the literature until recently. While the nature of the nursing and radiography disciplines may lead radiography educators to believe that PBL use in radiography education may be appropriate, based on existing research in nursing, its effectiveness and student attitudes need to be researched before curriculum-wide implementation is planned.

A mixed methods evaluative case study was conducted to investigate if a PBL module had an effect on radiography students' image critique skills and their perceptions related to PBL. Quantitative data collection instruments consisted of a pretest and a posttest to assess students' image critique skills before and after PBL. Qualitative data collection instruments included a pre- and post-PBL survey, as well as structured reflections after the PBL module.

The results showed a statistically significant difference between the pretest and the posttest, suggesting that the PBL module improved image critique skills. In addition, students report to feeling significantly better prepared for image critique after PBL, and perceived working in a group as a good way to practice critiquing images. Difficulties reported were related to group-related issues and transitioning to PBL, most likely due to being accustomed to lecture-based instruction.

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CHAPTER ONE: INTRODUCTION

Problem Statement

Numerous studies have been conducted to examine the effectiveness of problem-based learning (PBL) in higher education programs that prepare health professionals for their clinical careers, as evident in recent syntheses that focus on this topic (Albanese & Dast, 2014; Jin & Bridges, 2016; Newman, 2003). Even though the very first implementation of PBL was designed for small-group learning in medical education, PBL has been adopted in other graduate level educational programs such as nursing, dental, and occupational therapy (Gunn, Hunter, & Haas, 2012; Schmidt, 2012; Shin & Kim, 2013; Williams & Beattie, 2008). The use of PBL has also been studied in undergraduate nursing programs (Arrue, Ruiz de Alegría, Zarandona, & Hoyos-Cillero, 2017; Baker, 2000; Beers, 2005; Carvalho et al., 2017; Choi, Lindquist, & Song, 2014; Gholami et al., 2016; Rideout et al., 2002; Smith & Coleman, 2008; Tiwari, Lai, So, & Yuen, 2006). Undergraduate nursing education and radiography education have similarities, such as common educational goals and a program structure that includes both didactic and clinical education components. However, the use of PBL in radiography education has not been documented in literature (Wilbanks, 2009) until recently. An EBSCOhost search conducted in June 2018 that focused on the use of PBL in radiography within the last ten years resulted in only four articles that discussed this topic (Kiguli-Malwadde, Businge, & Mubuukem, 2010; Kowalczyk, 2012; Takayoshi, Naomi, Kengo, Hidenobu, & Katsuhiko, 2016; Wilbanks, 2009). However, none of these articles describe original research that focuses on the effectiveness of PBL in radiography. Instead, they focus on students' and educators' perceptions related to PBL in radiography (Kiguli-Malwadee et al., 2010; Takayoshi et al., 2016), the role of the educator in the PBL process (Kowalczyk, 2012), or identifying the need to investigate the effectiveness of

PBL in radiography education (Wilbanks, 2009). While the nature of the nursing and radiography disciplines may lead radiography educators to believe that PBL use in the radiography education may be appropriate, based on existing research in nursing education, its effectiveness and student perceptions need to be researched further before curriculum-wide implementation is planned.

Research Questions

Given the lack of research of PBL use in radiography education, and the continued request from students to be better prepared to critique images upon the completion of the radiography program, this study aims to answer the following research questions by implementing a PBL instructional module focused on image critique skills of second-year radiography students:

1. How does PBL effect image critique skills of second-year radiography students?
2. What are students' perceptions regarding the use of PBL when learning how to critique radiographic images?

Key Terms

As the focus of this dissertation was on the effectiveness of PBL in radiography and student perceptions related to PBL, it is important to provide definitions of all related terms.

Radiography is the art and science of using x-rays to provide images of the human body for the purpose of diagnosing pathologic processes. Radiography education relies on a *radiography curriculum,* which is utilized to provide students with a foundational knowledge necessary to become a radiographer, while developing lifelong skills that will be utilized in their future careers (American Society of Radiologic Technology, 2017). One of many skills that radiography curriculum is built to develop is image critique. *Image critique* involves examining the quality of a radiographic image. A *radiographic image* is an image of human anatomy that is produced during a radiographic procedure, and is used for diagnosing pathological processes. Therefore, a radiographic image must be of a high diagnostic quality. The production of a diagnostic image involves an exponential number of *image critique variables*, including patient anatomy, pathology, radiographic positioning, radiation protection, x-ray equipment, technical factor selections, image acquisition, image processing, digital post-processing, contrast, image receptor exposure, spatial resolution, and distortion. Therefore, due to a large number of variables that can affect the quality of a radiographic image, as well as the possibility of these factors interacting with each other, there is an astronomical number of possible *imaging problems.* Imaging problems lead to images that are outside diagnostic acceptance limits. An image critique system uses the *diagnostic problem-solving process*, which requires radiographers to critically think through the problem and formulate hypothesis that attempts to resolve the greatest number of imaging problems. Determining if a radiographic image is within the acceptance limits is an initial step of the image critique process, followed by determining the cause of the problem, which starts the problem-solving part of the process. The determination of acceptability tends to be the most challenging part of image critique, as in most instances there is more than one cause, which complicates the problem-solving. Once causes are determined, the recommendation of corrective action can begin, which is the final step in the problem-solving process. Being able to identify the appropriate corrective action is rather challenging, as this skill is acquired through clinical experience and based on extensive knowledge in image critique variables. Therefore, image critique is considered a moderately structured problem, even for experienced radiographers (Carlton & Adler, 2013). As a result, students struggle with this problem-solving process, especially when an image is outside of acceptance limits, and because of its complexity as many possible corrective actions could be utilized, with multiple solutions and solution paths. However, it is expected that students enter the workforce with this essential real-world skill, which is utilized frequently in clinical practice. The ability to detect and correct errors that affect image quality involves problem-solving that requires experience, as well as the use of skills acquired in clinical coursework, and knowledge gained in didactic courses. While the curriculum aims to develop these skills throughout radiography education, those are not always directly taught and students do not get many opportunities to practice problem-solving related to image critique outside of the clinical setting, where critique and final decision regarding image quality is left up to a radiologic technologists. *Radiologic technologists* are licensed radiographers who are in charge of reviewing all images produced by student radiographers, and determining if images are acceptable or need to be repeated. The only opportunity to practice image critique is provided when students perform procedures during their clinical education. *Clinical education* is the competency-based practical component of radiography programs during which students interact with real patients and practice performing radiographic procedures in a variety of healthcare facilities, including hospitals and outpatient clinics, which are also known as *clinical sites*. Even though students are presented with opportunities to practice image critique with their instructors at the clinical sites, this is an infrequent practice as the clinical instructors are busy working with multiple students. Additionally, assessment of image critique skills is often delayed until the final clinical course, in the second year of the program. Therefore, providing opportunities for students to learn how to apply a systematic image critique method, and practice one of the most complex skills of the profession is essential, as it helps lead to the best possible patient care (Carlton & Adler, 2013).

CHAPTER TWO: LITERATURE REVIEW

This literature review discusses the definition and history of PBL. Similarities between radiography and nursing education needs and goals are discussed and research outcomes related to learning in undergraduate nursing programs and attitudes of nursing students related to PBL are explored. Finally, the use of PBL in radiography is discussed.

History and Definition of PBL

PBL was first introduced in 1969 at the McMaster University as a new instructional approach to medical education, which was in response to medical students' dissatisfaction with having to memorize information that they perceived to have little relevance to clinical practice. Motivated by this innovative approach and influenced by the General Professional Education of the Physician and College Preparation for Medicine, which called for changes in medical education, new medical schools develop their own PBL curricula, while some existing schools with conventional curricula converted to PBL with focus on development of clinical reasoning and problem-solving skills (Barrows, 1996). This dissemination of PBL in medical schools was followed by other education disciplines such as nursing, engineering, law, social and life sciences, amongst others (Baker, 2000; Hmelo-Silver, Derry, Bitterman, & Hatrak, 2009; Schmidt, 2012).

Problem-based learning is an "instructional method in which students learn through facilitated problem solving" (Hmelo-Silver, 2004, p. 235). PBL typically involves a small group of self-directed learners who develop content knowledge, critical thinking strategies, and collaborative learning skills through a facilitated experience of solving meaningful, authentic problems (Ertmer & Glazewski, 2019; Hmelo-Silver, 2004). According to Barrows (1994), who is considered a leader in the work with PBL (Ryan, 1993), the purpose of this active learning is not only to develop self-directed learning skills, but also to instill the responsibility for lifelong learning and continued professional growth. Albanese and Mitchell (1993) described PBL as "an instructional method characterized by the use of patient problems as a context for students to learn problem-solving skills and acquire knowledge about the basic and clinical sciences" (p.53). Furthermore, PBL can be described as experiential learning during which knowledge is actively constructed in collaboration within a small group (Hmelo-Silver, 2004), and as such connects most closely with the constructivist learning theory (Kantar, 2014; Posner, 2004; Savery & Duffy, 1995). The connection between the two is best described by Savery and Duffy (1995), who stated that PBL is "one of the best exemplars of the constructivist learning environment" (p. 135). The goals of PBL can be described as "helping students develop: 1) flexible knowledge, 2) effective problem-solving skills, 3) SDL [self-directed learning] skills, 4) effective collaboration skills, and 5) intrinsic motivation" (Hmelo-Silver, 2004, p.235). While all these goals are essential to the PBL process and are an important part of a PBL research agenda (Hmelo-Silver, 2004), the following sections of the literature review will discuss research outcomes focusing on goals related to student learning and attitudes, due to the questions selected to guide this research study. The similarities between radiography and undergraduate nursing education will be reviewed first, to reiterate the application of PBL to nursing and connections between nursing and radiography.

Comparison of Radiography and Nursing Education Needs/Goals

Changes in healthcare and implementation of technology to better the quality of patient care and improve patient safety have placed an increased responsibility on higher education institutions to train healthcare team members, such as doctors, pharmacists, physician assistants, nurses, and radiographers, in a variety of skills. These skills are not only focused on diagnosis and patient care, but also on being able to use evolving technologies to assist in patient care, which adds a requirement for another layer of critical thinking and solving complex problems to day-to-day routine of healthcare team member responsibilities. Therefore, teaching methods used in healthcare education need to improve, including methods for improving critical thinking and problem-solving abilities (Carvalho et al., 2017; Sangestani & Khatiban, 2012). This particular need has been emphasized in both undergraduate nursing and radiography education. Critical thinking and problem-solving abilities are at the forefront of both professions, as they are crucial for safe nursing practice (Beers, 2005; Kong, Qin, Zhou, Mou, & Gao, 2014), as well as improved quality care and patient safety in radiography (Kowalczyk, 2011; Pieterse, Lawrence, & Friedrich-Nel, 2016). Radiography and nursing educators must be able to support these needs and produce quality graduates. Curricula for both programs are designed to match the professional standards and assure that graduates possess the essential clinical skills they need to become successful practitioners in their respective professions. Additionally, these educational programs must prepare students to take certification examinations that are required for gaining employment upon graduation (American Society of Radiologic Technologists, 2017; National Council on State Board of Nursing, 2017).

Both radiography and nursing graduates should exhibit a number of professional characteristics, which include providing optimal care to diverse patient populations, while dealing with the challenges related to the dynamic healthcare environment. Working in such an environment requires application of theory to practice, utilization of problem-solving skills, and collaboration with other members of the healthcare team. Self-directed, lifelong learning is essential to both professions (American Society of Radiologic Technologists, 2017; Pew Health Professions Commission, 2000; Williams, 2001). Graduating professionals with these characteristics is a common goal that radiography and nursing educators share. Because of the similarities between undergraduate nursing and radiography education, and due to a lack of empirical research that studies PBL in radiography, research outcomes in nursing education related to learning and student attitudes are reviewed.

Research Outcomes Related to Learning

Development of flexible knowledge is one of the goals of PBL. This goal involves going beyond acquiring declarative or factual knowledge, where students simply learn the facts, and it requires synthesizing information across multiple domains (Hmelo-Silver, 2004). Although flexible knowledge is emphasized in PBL, educators should not dismiss the importance of factual knowledge, because in order to be able to synthesize flexible knowledge, students must first build factual knowledge. Consequently, developing factual knowledge is an integral part of nursing undergraduate education, and is assessed on the certification examination that is required for gaining employment. Therefore, studies that evaluate if PBL can be used to develop factual knowledge need to be considered. For example, one study compared the objective test scores of 36 nursing students, who were taught diabetes-related content using PBL with 18 who were taught with the conventional lecture method. The results revealed no statistically significant difference in the test scores, suggesting that PBL is just as effective as traditional lecture for learning factual information that is measured by an objective test (Beers, 2005). Although this particular research did not include any details related to PBL implementation, which limits its reliability, its conclusions align with another study that used a similar design, but in addition to studying factual knowledge, focused on argumentative knowledge (supporting statements with evidence). In this quasi-experimental study, the authors compared pretest and posttest scores between two groups of undergraduate nursing students. While both groups learned topics related to patients diagnosed with depression, one group received traditional lecture instruction (n=57), while the other group was exposed to PBL (n=57). The results did not show any statistically significant differences between the two groups in factual knowledge, but did find significant improvement in argumentative knowledge for the group that learned with PBL (Arrue et al., 2017).

Development of effective problem-solving skills, which is the second goal of PBL, involves “the ability to apply appropriate metacognitive and reasoning strategies” (Hmelo-Silver, 2014, p. 240). The importance of cognitive and metacognitive skills, including critical thinking ability, have been emphasized in the nursing education literature (Josephsen, 2014; Kong et al., 2014). A study by Gholami et al. (2016) compared critical thinking skills and metacognitive awareness in a traditional lecture and PBL with undergraduate nursing students enrolled in a critical care course. This study utilized pretest-posttest design and involved only a single group of participants. The lecture method was implemented over an eight-week period, followed by the PBL module during the second eight-week period of the same course. Standardized questionnaires were administered to all participants before the course started, and after each eight-week period, to investigate participants’ critical thinking skills and metacognitive awareness. The results showed no significant differences between the scores obtained before and after the traditional lecture method. However, a significant improvement in the critical thinking and metacognitive skills scores was noted after the PBL component, indicating that PBL methods had a positive impact on these abilities (Gholami et al., 2016). Another study by Tiwari et al. (2006) had a similar focus. The authors compared the effectiveness of PBL in developing critical thinking skills of 40 undergraduate nursing students to 39 of their peers who were taught using a traditional lecture approach. Critical thinking disposition was measured using standardized questionnaires, along with individual interviews that were designed to gather students' perceptions related to their learning experience. Results revealed that the critical thinking scores were not significantly different between the two groups at pretest, but were significantly higher in the PBL group at posttest. Furthermore, the PBL group continued to have higher scores for two years afterwards, although the group differences diminished. The study concluded that in addition to being an effective instructional strategy in developing critical thinking skills, PBL can lead to increased student satisfaction. When asked about what contributed to the development of their thinking, students who were assigned to the traditional lecture indicated that they did not feel encouraged to think, while their peers shared that the PBL tutorial process including peer support were most influential (Tiwari et al., 2006). Even though Gholami et al. (2016) and Tiwari et al. (2006) found PBL to be superior to traditional lecture in development of critical thinking skills, a similarly designed quasi-experimental study concluded otherwise. Choi et al. (2014) compared critical thinking, problem-solving, and self-directed learning skills of 46 nursing students, who were exposed to PBL to 44 of those who were taught in a conventional lecture using a pretest-posttest design consisting of standardized questionnaires. While learning outcomes were positively correlated, they were not statistically different between the two groups, indicating that PBL was not superior to a traditional lecture.

Based on the research studies in nursing education related to learning outcomes reviewed here, it can be concluded that PBL seems to have similar effectiveness to traditional methods when the outcomes are related to factual learning, but PBL appears to be superior to traditional lecture methods for developing argumentative knowledge. When critical thinking and metacognitive skills are evaluated, PBL seems to be either just as effective as or more effective than the lecture method, while self-directed learning skills and problem-solving appear to be equally developed using either method (Choi et al., 2014; Gholami et al., 2016; Tiwari et al., 2006). It is important to note that the studies reviewed had limitations. The quality of the lecture was not considered in the comparison studies, and learning is highly dependent on the design of the lecture and the skill of the person delivering it. Furthermore, the description of PBL implementation was not very detailed in these articles, and therefore, may be considered ambiguous, which affects the reliability of these studies. Internal validity threats have also been recognized. For example, the results of the study conducted by Gholami et al. (2016) may have been a function of time, as PBL was implemented in the second half of the semester, after the lecture method had been utilized during the first half. Similar research that changes the order in which these two instructional methods are implemented would be useful in excluding the maturation threat to internal validity. Follow-up was not conducted in all studies (Beers, 2005; Arrue et al., 2017; Gholami et al., 2016; Choi et al., 2014) to assure that students are retaining the skills they acquired, which is a useful data point that is provided only in one of the studies reviewed (Tiwari et al., 2006). The rationale for sampling decisions was not clear, as there is no mention of any statistical power analysis, which leaves the suitability of the sample sizes questionable. Additionally, an uneven number of participants in control and treatment group was noted (Beers, 2005), and the reason for this imbalance was not addressed in the article. Lastly, while the research studies related to critical thinking and metacognition lead to mixed results, challenges related to the assessment of PBL should be considered (Savin-Baden, 2004), as the suitability of the assessment methods used in these studies is unknown. Considering the limitations of the above mentioned studies, there seems to be a lack of high-quality empirical evidence regarding the learning outcomes associated with PBL, which can make the implementation of PBL in nursing challenging.

Research Outcomes Related to Student Attitudes

Because PBL is widely used in nursing education for improving professional and personal skills (Rideout et al., 2002), it is critical to capture students' perceptions and attitudes related to this instructional approach. While studies that concentrate on reporting students' attitudes are important to our understanding of PBL, it must be acknowledged that most of such studies rely on self-reported data, which has a limitation bias that is inherent in self-reporting (Hmelo-Silver, 2004), as well as recall and socially desirable response biases (Tiwari et al., 2006).

A mixed methods research study that compared knowledge gains between two groups of students who were exposed to PBL and traditional lecture explored student satisfaction, revealing that students had positive attitudes toward PBL (Tiwari et al., 2006). Data collected using interviews was analyzed and revealed that the students who were in the PBL group described their learning experience as "enjoyable, inspiring and self-fulfilling; however, the opposite was expressed by the lecture students, who were quite negative about their learning experience" (Tiwari et al., 2006, p.551). A second mixed methods study (Ryan, 1993) was conducted with 35 nursing students to explore the relationship between PBL and students' perceptions of their learning in a course that was designed to develop self-directed learning skills through PBL. When students' perceptions about the importance of self-directed learning were compared across the semester, highly significant changes were noted. Similarly, students' perceived ability as a self-directed learner showed a significant increase, from low-moderate at the beginning of the semester, to moderate-high at the end of semester. A third study (Rideout et al., 2002) compared a group of 45 nursing students graduating from a problem-based curriculum with those graduating with 31 students completing a conventional nursing program used a self-report questionnaire to compare students' perceptions related to preparation for clinical practice, nursing knowledge, and skills. The results indicated no statistically significant differences in student perceptions. Comparing the pass rates on the National Nursing Registration Examination between the two groups also revealed no statistically significant differences, but a slightly higher percentage of the conventional group passed the examination (98%) compared to the PBL group (93%). However, there was a significant difference in admission averages between two groups, with the conventional group having a higher average, which could have contributed to a higher pass rate. It is also important to note that the PBL students in this study reported a higher level of satisfaction with their education. Lastly, another study (Smith & Coleman, 2008) utilized qualitative methods to focus on the experience of 11 registered nurses who were part of a nursing program designed to prepare them for specializing in pediatrics nursing over a one-year period. Focus group interviews were conducted at the completion of the program to capture participants' perceptions about their learning experience and six months after to collect data related to the impact the PBL program on their practice. Data analysis revealed themes related to difficulties participants had transitioning to PBL, which resulted in negative perceptions that were reported during the first set of interviews. However, six months later, students expressed "increased confidence, assertiveness, being more questioning of practice and likely to search for and use evidence to underpin practice than before this PBL programme" (Smith & Coleman, 2008, p.144). The authors concluded by emphasizing the importance of getting students acquainted with the PBL process, as well as offering ongoing support to address student concerns during PBL delivery (Smith & Coleman, 2008).

The research outcomes outlined above indicate that student perceptions related to the overall PBL experiences in nursing education were mixed. While some studies found that students had a positive PBL experience, as opposed to their counterparts who were exposed to lecture methods (Rideout et al., 2002; Tiwari et al., 2006), others found that perceptions were the opposite, as they reported difficulties with transitioning to PBL (Smith & Coleman, 2008). It is difficult to determine the cause of this discrepancy, as some authors did not share much detail regarding how PBL and lecture were delivered (Smith & Coleman, 2008; Rideout et al., 2002), similar to studies related to learning outcomes discussed above. Additionally, studies that focused on perceptions regarding specific skills, such as those of a self-directed learner, and outcomes like preparation for clinical practice, showed either positive effects (Ryan, 1993) or no effects related to PBL (Rideout et al., 2002). While this research seems to be promising when it comes to the use of PBL in nursing, due to higher student satisfaction with PBL methods compared to lecture, it is important to acknowledge that studies that focus on student perceptions may not be an accurate description of their skill levels. This may be due to inflated confidence that PBL students may experience because of the increased satisfaction with PBL, as well as building relationships with their tutors and peers while working in a small group. Therefore, additional research that uses assessment appropriate to measuring these complex constructs is needed before definitive conclusions are made regarding nursing student attitudes and perceptions related to PBL.

While research studies reviewed here do not clearly indicate that PBL could support nursing goals, alignment between undergraduate nursing education goals and those of PBL is evident. Even though PBL research in nursing education is more extensive than in radiography, the quality of some studies reviewed above is not sufficient to reach firm conclusions. Furthermore, given the limitations of those studies and the complexity of the construct, we cannot conclude that PBL is superior to the conventional lecture approach. Even if we were able to come up with such a conclusion, it is not clear that the findings can be generalized to radiography education, regardless of the similarities between these two fields. However, quality research that studies the benefits and limitations of PBL in nursing education can be used as a model in designing research studies that focus on the use of PBL in radiography, which is much needed to inform the practice of radiography educators.

Use of PBL in Radiography

The development of critical thinking skills is essential for all students in the health professions (Pew Health Professions Commission, 2000). The definition of critical thinking has been debated in a variety of educational contexts and a recent review of the literature related to defining this concepts confirms this controversy (Ghanizadeh, 2017).However, critical thinking for radiographers may be "…described as a purposeful exercise resulting in evaluation and inference to explain contextually based situations on which to base reflective judgment" (Kowalczyk, 2011, p.120). One of those situations involves image critique, which is the process of evaluating images based on diagnostic problem-solving and requiring radiographers to think critically through the problem. According to research outcomes in nursing education related to critical thinking and metacognitive skills discussed above, which showed that PBL is either as effective or more effective than the lecture method, PBL could be used to improve critical thinking skills in radiography students. However, even though most allied health educational programs have implemented PBL to increase critical thinking skills, radiography educators have been slow in doing so. In a study that focused on exploring the concept of critical thinking development in radiography, a majority of 295 educators (89.49 %) indicated that they teach critical thinking using traditional lecture methods (Gosnell, 2010). To investigate the lack of use of PBL in radiography, Kowalczyk (2011) sent a survey to program directors of accredited radiography and radiation therapy programs. Based on the responses of 317 program directors, the study concluded that educators did not have sufficient skills or resources needed to adopt PBL. Specifically, the study identified a "[l]ack of curriculum development skills necessary to implement problem-based learning (PBL), unfamiliarity with the best techniques to assess student critical thinking skills, and a perceived lack of resources to implement the changes needed to effectively teach critical thinking skills" (Kowalczyk, 2011, p.120). As a result, radiography educators are continuing to use traditional lectures instead of implementing learning strategies, like PBL, that may be more effective in developing students' critical thinking skills, which are essential to image critique.

CHAPTER THREE: DESIGN CASE

This chapter provides a detailed description of the PBL module, including the learning activities, course materials, facilitation techniques, support, resources, and assessments utilized in the module. In addition, the implementation of the PBL module is described in terms of its fidelity and weekly summaries, reflections, and adaptations.

PBL Module and Course Materials

To research if PBL could be used to support student learning related to image critique, the following PBL module was planned by the researcher, who also served as the PBL facilitator during the delivery of the module. This section outlines the plan for the PBL delivery, which consisted of the introduction to the PBL process, learning activities, facilitation techniques, support and resources, as well as the assessment methods in a radiography education context.

Introduction to the PBL Process

While some of the participants in this study may have been introduced to PBL in courses outside of the radiography curriculum, the majority of them were new to PBL, due to them experiencing more traditional instructional methods and direct guidance, which are the predominant pedagogical methods used in the program. Therefore, the students needed to be introduced to this instructional approach, as most would not know what to expect from the PBL process (Woods, 1996). Additionally, the students needed to learn about the change in classroom dynamics associated with PBL that is due to the shift of classroom activity from the instructor to the student. To familiarize students with the PBL process, the researcher recorded a screencast that was shared with students using Canvas, the learning management system (LMS) platform used at study site, Indiana University Northwest (IUN). The recording explained the following items, on a conceptual level:

- Overview of the PBL process
- Introduction to student roles
- Introduction to facilitator role
- What is expected of students

The screencast also outlined some of the details related to requirements for this PBL module, including group work, learning activities, pre- and post-test, and survey participation, as well as descriptions, expectations, and assessments related to the following assignments:

- Verbal reports of group discussions
- Oral group presentation
- Peer- and self-assessment
- Structured reflection paper

Learning Activities

The learning activities were designed relying on the STELLAR course development system and eStep activities described by Derry, Hmelo-Silver, Nagarajan, Chernobilsky, and Beitzel (2006). STELLAR (Socio-Technical Environment for Learning and Learning-Activity Research) was designed to help college students develop the following attributes:

> 1) meshed cognitive representations (representations bringing together course concepts with perceptual visions of practice and plans for practice), which should support spontaneous transfer of course knowledge to professional practice; and 2) mindsets for collaboration, self-directed learning, and reflective practice in tool-rich environments, which may help support life-long professional growth. (Derry et al., 2006, p. 146-147)

Given these intended outcomes, even though STELLAR was designed for preservice teachers, this course development system was found to be appropriate for use in this module, with some adaptations.

To accomplish the first STELLAR goal of developing meshed cognitive representations, learning activities described in Steps 2 through 4 were developed, as outlined in Appendix A, which details all learning activities for this PBL module, as well as the alignment between goals and assessment. A real-life problem was presented as a realistic situation that students may confront as future radiographers. The problem included a radiographic image of poor quality that was obtained in clinical practice that was prepared to guide this learning experience and initiate student engagement and was introduced in Step 2. The image (Appendix B) was intended to resonate with student experiences, and therefore stimulate recall of concepts previously learned. Simply introducing the problem does not initiate student inquiry, which has been recognized as one of the difficulties that students who are new to PBL tend to experience (Ertmer & Glazewski, 2015). To help mitigate this issue and initiate student buy in, the scenario was presented using a video format. The video showed a day in the life of a radiographer who made an exposure for a trauma hip procedure, but did not position the patient, and therefore, did not know at all how the patient was positioned or what lead to the errors on the resulting image, leaving it up to the students to solve the problem and come up with a plan related to improving the image for the repeated examination (the video script is provided in Appendix C). To elevate the purpose, the facilitator prepared a discussion that focused around the importance of image critique, which included presentation of selected resources related to medical malpractice in radiography that resulted from poor image quality, and included real examples to use as a hook designed to increase engagement and motivation (Appendix D). Additionally, constraining the task is recommended in the literature, for those who are new to PBL, and could be accomplished through use of variety of techniques, such as providing graphic organizers and interim deadlines (Ertmer & Glazewski, 2015). This was prepared for Step 3, during which students reviewed a graphic organizer that outlined learning activities, assessment, and deadlines (Appendix E). Additionally, assigning student roles and establishing ground rules was also planned for this step, to initiate collaboration, and thereby support the second STELLAR goal.

The second STELLAR goal for this module was established to help students develop skills related to self-directed learning, collaboration, and professional development, as well as reflective practice. The initiation of this self-directed process was planned for Step 4, where students are tasked with identifying learning gaps by answering a "What do I need to know?" question of the KWH part of the chart, which also includes "What do I want to know?" and "How do I find out?" questions (Appendix F). This process was also designed to support the development of meshed cognitive representations. During Step 5, students defined the task and generated hypotheses, using a FILIAP worksheet (Appendix G). This worksheet was established to record information that was relevant to the problem, consider initial ideas and learning issues, as well as develop an action plan (Hmelo-Silver & Ferrari, 1997) and set learning objectives. Hard scaffolds were prepared to facilitate the continuation of the group process, as outlined in the facilitation techniques section below. In Step 6, students conducted additional research using IUN Library databases to gather information necessary to solve the problem. They also completed other actions assigned at the previous group meeting. The self-directed process that prepared students for professional development was designed to minimally familiarize them with professional journals, and set in motion a desire for lifelong learning and professional development, supporting the second STELLAR goal. Steps 5, 7, 8, and 9 were developed to promote mindset for collaboration. During these steps, the students worked with their group members to create a group response to the problem and organize it in a final presentation. Steps 7 and 8 were designed to provide collaboration time and engage students in the discussion that was designed to result in a shared understanding and a solution outlined in the final presentation, supporting both STELLAR goals. The grading rubric and other hard scaffolds that were selected to help students prepare a response that meets the criteria outlined in the rubric were also prepared and are explained in the Facilitation Techniques section below. Step 9 includes the delivery of student presentations, as well as an opportunity for the facilitator and other clinical faculty to assess content learning and presentation delivery skills. A debriefing exercise was planned for the completion of this step, during which instructors and the facilitator could share with students their feedback, providing the students with the opportunity to reflect on their own overall group accomplishments. Reflective practice, consistent with the second STELLAR goal, was initiated as students reflected on the PBL process by completing a structured reflection assignment in Step 10, as well as during self-assessment in Step 11.

Facilitation Techniques

Facilitation techniques, including how groups would be formed, anticipated difficulties, and scaffolding were considered next.

Forming groups. Groups were formed using the clinical placement schedule, which the radiography program uses to divide the class into clinical groups for the purpose of placement at the nine clinical affiliates, where students complete their clinical education. The clinical placement schedule was used because the individuals belonging to the same PBL groups already worked together in the clinical setting, and therefore, should have been more comfortable collaborating with each other during this module. In this instance, there were 33 students at nine clinical affiliates divided into groups consisting of two to five students. To make the groups similar in size, groups that consisted of two or three students were combined, resulting in seven groups of four to five students. At their first face-to-face meeting, group members were asked to establish ground rules, as well as select individual group member roles. The following roles were assigned:

- Timekeeper – makes sure that the group stays on track (one group member)
- Summarizer – provides a summary of the discussion for other students to approve or amend, and delivers verbal reports at the end of each group discussion (one group member)

- Recorder – takes notes on the whiteboard (one group member)
- Team member – participates in discussion and reviews resource materials (one to two group members)

Anticipated difficulties. Difficulties related to implementing PBL that have been identified in the literature (Belland, Kim, & Hannafin, 2013; Ertmer & Simons, 2006; Ertmer & Glazewski, 2015) were anticipated in this research. One of those difficulties considered was active student engagement (Belland et al., 2013) as well as sustained participation through the life of the problem, which becomes an issue when students do not use their group time productively. To support sustained engagement and participation, frequent student check-ins that provide opportunities for students to share what they have learned have been recommended (Ertmer & Simons, 2005; Ertmer & Glazewski, 2015). Consistent with this recommendation, verbal reports were used as frequent check-ins during this module. The reports were delivered by individual groups at the conclusion of each discussion to outline group accomplishments using evidence on their whiteboard.

Accountability and fair workload distribution have also been identified as a potential issue, especially in large classes (Woods, 1996). Peer- and self-assessments (Appendix H) were designed to help minimize these problems, as recommended by Woods (1996). An additional difficulty that was considered in this research was adjusting to student-centered learning environment (Asghar, Ellington, Rice, Johnson, & Prime, 2012; Goodnough & Cashion, 2006). To support this adjustment and the transformation of responsibility, sufficient scaffolding had to be provided (Ertmer & Glazewski, 2019), as outlined below.

Scaffolding. Scaffolds are used in PBL to help initiate student inquiry, promote concept integration, resolve misconceptions, as well as promote reflective thinking, and can come in many forms (Simons & Ertmer, 2005). Scaffolds that are anticipated in advance and can be prepared during the planning stages of PBL are known as hard scaffolds. The following hard scaffolds were prepared for this PBL module:

1. To support development of meshed-cognitive representations and content knowledge, chapters from the following textbooks were selected to be provided in Step 5:
    a. Long, B. W., Curtis, T., & Smith, B. J. (2016). *Merrill's atlas of radiographic positioning and procedures* (13th ed.). St. Louis, MO: Mosby/Elsevier.
    b. Carlton, R. R., & Adler, A. M. (2013). *Principles of radiographic imaging: An art and a science* (5th ed.). Clifton Park, NY: Delmar/Cengage Learning.
    c. McQuillen-Martensen, K. (2006). *Radiographic image analysis*. St. Louis, MO: Elsevier Saunders.
2. To support professional development and self-directed learning, a procedure guide that directs students to IUN library databases (Appendix I) was prepared for Step 6.
3. To support the development of collaboration skills and outline what is expected of students, a Peer/Self-Assessment Instrument (Appendix H) was designed for Step 3.
4. To support students in creating a final group presentations that may fulfil the expectations, a grading rubric (Appendix J) was developed for Step 8, with addition of the following scaffolds:
    a. Applying the Assertion-Evidence Framework to Presentation Design (https://www.slidegenius.com/blog/applying-assertion-evidence-framework-presentation-design/)

b. Outlining a Presentation Using the Assertion-Evidence Slide Design (http://linksglobal.org/AMI/extras/03_EffectivePresOutlining_FINAL_092911.pdf)
c. http://sixminutes.dlugan.com/assertion-evidence-design-presentation-slides/
d. How to Make a Great Presentation (http://higherelearning.com/make-great-presentation-powerpoint-using-assertion-evidence)
e. Delivering a Great Presentation (https://www2.le.ac.uk/offices/ld/resources/presentations/delivering-presentation)

Soft scaffolds are those that cannot be anticipated and can be delivered as just-in-time instruction. Some examples include providing new information based on students' needs or students' requests, as well as asking questions to clarify or verify student understanding (Ertmer & Glazewski, 2019). Therefore, the need for soft scaffolds could not be planned, but was identified by the researcher/facilitator during student discussion, through close monitoring of the PBL process. The researcher/facilitator planned to continually rotate among groups to monitor their discussion as well as serve as a metacognitive coach who guides the development of higher order thinking skills through metacognitive questions and modeling.

The researcher/facilitator planned to use questioning techniques that push students for explanations during group discussions. These techniques involved 'how' and 'why' questions to stimulate synthesis, analysis, and evaluation of information that students bring up during the discussion, particularly in Steps 4 through 7 (Appendix A). The goal of questioning techniques was to help develop students' clinical reasoning while steering their focus away from the lower cognitive level domain. To challenge students to apply what they already know, the researcher/facilitator planned to utilize revoicing and summarizing, especially as students generate hypotheses. As the researcher/facilitator steps into the role of a metacognitive coach, she planned to utilize metacognitive questions, which are “domain general and refer to planning, monitoring, controlling, and evaluating the problem-solving process” (Hmelo-Silver & Ferrari, 1997, p.412), rather than cognitive questions, which “address domain-specific knowledge and procedures needed to solve the problem” (Hmelo-Silver & Ferrari, 1997, p.412). To help accomplish this, the following strategies were planned:

- Jump starting – asking students about how they will approach the problem
- Check-ups – asking students to think about how what they are discussing relates to their goal of solving the problem
- Stepping back – asking students to step back and talk about their goals, which assures that they remain focused on the problem
- Dropping hints – helping students move forward when they are stuck in the problem-solving process (Hmelo-Silver & Ferrari, 1996).

Support and Resources

The Canvas LMS was used to provide technology support, to record and share the screencast that introduces the PBL process, as well as to share the video that introduced the radiographic image and the problem scenario with guiding questions, which were presented to the group in Step 3 of this module. Also provided in Canvas were a link to an interactive whiteboard (https://webwhiteboard.com/) that was used as a collaborative workspace, assignment descriptions, and corresponding assessment rubrics, along with other resources and hard scaffolds as discussed above.

Assessment

Studies related to summative assessment in the context of PBL points to some common methods that could be used to assess individual learning, including peer-assessment and self-assessment (Klegeris & Hurren, 2011; Papinczak, Young, Groves, & Haynes, 2007; Savin-Baden, 2004). Group work can be assessed through presentations and group projects (Kelly & Finlayson, 2007; Reynolds & Kearns, 2017; Savin-Baden, 2004). Additionally, formative assessment is recommended to support learning and may include "minute papers (Angelo & Cross 1993) and verbal reports of group discussions" (Reynolds & Kearns, 2017, p. 19). Based on these recommendations, student learning in this PBL module was assessed using verbal reports of group discussions, a group oral presentation, peer- and self-assessment, and a structured reflection paper, which were completed one week after the PBL module.

Verbal reports of group discussions. Verbal reports were used to assess the second STELLAR goal, which was to help students develop skills related to self-directed learning, collaboration, professional development, and reflective practice. This assessment was also used formatively to support student learning, discover misconceptions, and allow for metacognitive coaching. One group member, the summarizer, delivered the report at the conclusion of each discussion, outlining the group's accomplishments using evidence on their whiteboard. The researcher/facilitator used these reports as an opportunity to provide feedback and help students establish a shared understanding, maintain their agenda, and accomplish their learning objectives through metacognitive coaching.

Group oral presentations. Oral presentation was used to assess evidence of content learning indicated in the first STELLAR goal of developing meshed cognitive representations, as well as development of oral communications skills. While the development of oral communication skills is not one of the STELLAR goals, this criterion was included due to importance of oral communication in the radiography curriculum. The grading rubric (Appendix J) was used to assess this final product of group work.

Peer- and self-assessment. In addition to providing evidence of learning through verbal reports of group discussions and oral presentations, students assessed their own learning process and that of their peers using peer- and self- assessment (Appendix H). This instrument was adapted from Papinczak et al. (2007) to help hold students more accountable as well as to measure “constructs or domains of performance that were extensively reported in medical and nursing education literature” (Papinczak et al., 2007, p.124) including responsibility and respect, information processing, communication, critical analysis, and self-awareness. The instrument was validated by Papinczak et al. (2007) and was found to have high values for Cronbach’s alpha (0.76 to 0.84), indicating strong internal consistency, as well as Pearson correlation coefficients of 0.40 to 0.60, implying acceptable reliability. It was also found to be easy to use by the students who participated in a pilot study conducted by Papinczak et al. (2007). Therefore, this instrument was selected for both peer- and self-assessment, to measure the development of skills related to self-directed learning, collaboration, and reflective practice that are outlined in the second STELLAR goal. Each student completed the instrument for all group members, including themselves, rating 16 categories on a scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*), totaling 80 points per evaluation.

Structured reflection. The students were asked to reflect on the PBL process at the conclusion of the module to assess the development of skills related to reflective practice outlined in the second STELLAR goal. The reflection was initiated by first answering the LAQ portion of the KWHLAQ chart (Appendix F), which included the following questions: “What did I learn?", "What action will I take?", and "What new questions do I have?". Additional questions were included to expand student reflection, which is an important part of the PBL process, due to its metacognitive nature. This assignment was designed to help students think about what they have learned, and reveal their perspectives about the learning process. Students received instructions regarding this assignment via Canvas (outlined in Appendix K).

Pretest-posttest. A pretest-posttest was administered to assess students' image critique skills before and after the PBL. As this assessment was also one of the data collection instruments, it is described in more detail in the next chapter.

Implementation

Fidelity of implementation is explained, followed by the weekly summaries of each meeting, which outline the implementation plan, reflections, and adaptations, as recorded by the researcher/facilitator.

Fidelity of Implementation

Fidelity of implementation refers to the extent to which what is planned is delivered as intended, and as such, affects the credibility of research. "Evidence-based practice assumes that an intervention is being implemented in full accordance with its published details" (Carroll et al., 2007, p.12). To assure credibility, in addition to providing the implementation plan, researchers need to document if the intervention had actually been implemented as planned (Carroll et al., 2007). To accomplish this, a diary form was developed to be completed by the researcher/facilitator at the beginning and conclusion of every PBL session, with the goal of outlining the implementation plan for each module, providing an opportunity for post-implementation summary/reflection, as well as detailing adaptations made during the implementation (Appendix L).

Weekly Summaries, Reflections, and Adaptations

The researcher/facilitator diary was completed weekly to outline the implementation plan, as well as to summarize the reflections and adaptations. Therefore, each weekly entry is outlined separately.

Week 1. The implementation plan was followed during the first week's meeting without any adaptations. While the first part of the meeting did not require facilitation, as students completed consents and surveys, as well as established group rules and selected group member roles, the facilitation was necessary while the students worked on the KWH part of the chart. The researcher/facilitator spent a few minutes listening to each group's discussion and getting involved whenever it became evident that they were not staying on task with answering the KWH questions, but instead discussing other questions, which could not be answered from the scenario. This was unexpected and challenging for the researcher/facilitator, who had to remind herself not to resort to lecturing to help answer students' questions. Instead, she reminded students to focus on the information that was provided, and instructed them that if they had questions that were relevant to the problem at hand, to include them on their chart and research them at the next meeting. The researcher/facilitator also had to utilize redirecting with two groups that were discussing questions that could not be answered, to help with shifting their focus and moving their discussions in the more appropriate direction. Based on other discussions related to what groups already knew, it became evident that the students were not prepared to critique the image. This helped the researcher/facilitator identify a chapter from McQuillen-Martensen's book, which focuses on the evaluation criteria for the axiolateral hip projection. Once all groups were done with answering KWH questions, they delivered their verbal reports. Six out of seven groups identified that they wanted to know how the radiograph was produced and what caused the errors, even though the researcher/facilitator explained that this would not be possible. Furthermore, it seemed that students were struggling with identifying learning gaps, justifying the use of the FILIAP chart, which was planned in the subsequent meeting. The implementation plan was followed without any adaptations, other than ending the meeting 10 minutes earlier than planned. Lastly, two adaptation were identified for the following week's meeting as a result of what the researcher/facilitator observed, as outlined in the Researcher/Facilitator Diary.

Week 2. The second week's meeting started with reviewing the video. The researcher/facilitator joined the group discussions using questioning techniques as needed and checking in with students who seemed frustrated. The students explained that their frustration was due to lack of information regarding the procedural aspects of the case, indicating that they wanted answers regarding the case, instead of identifying errors themselves and hypothesizing the cause of the problem. Even though it was tempting for the researcher/facilitator to deliver a mini-lecture to help move discussions past this source of frustration, she redirected students to the image instead, reminding them that they should be able to find some of the answers there, and that they would need to search for the remaining answer during the second part of the meeting that was reserved for performing research. While this worked for some groups, it did not for all. Two groups seemed to be stuck in a lower cognitive level and continued to repeat the same questions, indicating that the students were not prepared to analyze the image. Therefore, this seemed like the appropriate time to share the new resource identified after the previous meeting. This resource seemed to engage the students in applying the evaluation criteria and help resolve some of their frustrations. The researcher/facilitator took advantage of this and asked questions to stimulate critical thinking and initiate further discussions related to analyzing the image using revoicing. Through listening to group discussions, it was evident that at least one group was focused on procedural aspects, disregarding technical parameters and principles that could have impacted the quality of the radiograph. A soft scaffold was shared to help with this issue, and shortly after that, it was time to take a break and move to the computer lab. Once in the computer lab, students started to work on researching their questions, as well as organizing their presentations. Even though creating presentations was not planned until the following week, it seemed reasonable to make the adaptation to allow for this activity so that students could save the results of their research in their drafted presentation rather than saving that information in a separate document, which would have to be transferred to the presentation anyway. It also became evident that the students were revising their initial hypothesis as they gathered information. Even though this step was also planned for the following week, the researcher/facilitator decided not to interrupt as it seemed like a natural progression. At the conclusion of the meeting, students delivered their verbal reports indicating that they only needed to work on creating their presentations, which was a result of adaptations that were made during the meeting, as outlined above, which allowed for students to work ahead. The plan for the following week was therefore changed, with a possibility of eliminating one meeting.

Week 3. The third meeting started with distributing scaffolds related to the presentation, which was helpful to groups that already revised their hypothesis and were ready to start working on finalizing their presentations. However, two groups still needed to work on their hypothesis, so the researcher/facilitator asked them to step back and make sure that the hypothesis they were discussing aligned with their goal, reminding them to stay focused on the problem. Even though there were no adaptations for this meeting, one week was eliminated from the implantation schedule since the activities that were planned for the subsequent week had been conducted at the week 3 meeting, and the implementation plan was revised accordingly.

Week 4. The fourth meeting was the last face-to-face meeting and was reserved for the delivery of group presentations, followed by providing time for students to complete the post-PBL survey, as well as the posttest. The researcher/facilitator invited another didactic faculty member and clinical instructors to attend and evaluate group presentations using the grading rubric (Appendix J), while the researcher/facilitator assisted the students with projecting their PowerPoints. The best presentation was selected based on the points earned, and the winning group was announced and presented with a small trophy. Even though panel members were not asked to comment on student presentations, one of the members started to share her thoughts regarding the importance of image critique, as well as the quality of student presentations, so others followed, which was an unplanned, but an interesting way to finalize the face-to-face meetings.

Week 5. Since the last week did not include a face-to-face meeting, the only interaction with students was a reminder to complete the reflection and peer- and self-assessment, using Announcements in Canvas. Students were instructed to reflect on the PBL module by completing the structured reflection assignment, as well the peer- and self- assessment in Canvas. All participants submitted their assignments at the end of week 5 and the PBL module was concluded one week sooner than planned.

CHAPTER FOUR: METHOD

Method

This research utilized a mixed methods case study (Yin, 2014). A mixed methods approach can be advantageous as it affords the researcher the opportunity to utilize strengths of both qualitative and quantitative methods (Frankel, Wallen, & Hyun, 2011). Due to the complexity of the PBL phenomenon and its under-researched use in radiography education, it was believed that mixed methods were warranted as the combined advantages of qualitative and quantitative methods could provide stronger evidence for a conclusion (Frankel et al., 2011). Moreover, a case study design was selected because this method is recommended when a phenomenon needs to be studied in a real-life context and when the study is addressing the "how" or "why" research questions concerning that phenomenon (Yin, 2014). A case study can be carried out as descriptive, evaluative, and interpretive (Merriam, 1998). This case study was designed as evaluative, since image critique skills were evaluated with respect to the implemented PBL module. Furthermore, this study can be described as intrinsic, because with intrinsic case studies, "we are interested in it [the case], not because by studying it we learn about other cases or about some general problem, but because we need to learn about that particular case" (Stake, 1995, p. 3). The details of the intrinsic case and related issue of particularlizability are reviewed below.

Context

This study was conducted in a public higher education institution, the regional university campus of the Indiana University system located in an urban setting in Gary, Indiana. This institution has a total undergraduate enrollment of 5,000-6,000 and utilizes a semester-based academic calendar. The Radiography Program is offered by the Department of Radiological Sciences, which is a part of the College of Health and Human Services. The radiography program is a full-time day program involving classroom and laboratory experiences on campus and clinical experiences at local hospitals. The program is designed to prepare students, who receive an Associate of Science Degree in Radiography, upon completion, for professional careers as radiographers. The program is accredited by the Joint Review Committee on Education in Radiologic Technology (JRCERT), which is the only agency recognized by the United States Department of Education. The radiography program at IUN has been highly regarded for over 40 years and very effective in fulfilling its goals, one of which is to provide the medical community with graduates who are qualified to perform radiographic procedures, as outlined in the assessment data for the Radiography Program Effectiveness Measures, which are published on the program's website (http://www.iun.edu/radiologic-sciences/degrees/as-radiography.htm). Every June, the program admits 38 students who progress through the program as a cohort group. The group of 33 students who were accepted in 2017 were involved in this study. Their demographics were very similar to previous cohort groups over the past 10 years, including 31 females and 2 males, with an average age of 26.3. Their average college GPA upon admission was 3.38.

Sampling

Before deciding which sampling methods to utilize, it is recommended researchers consider the objective of their research. When a study does not aim to generalize to a population, but rather to obtain insights into a phenomenon, which was the case with this research, purposeful sampling should be utilized (Onwuegbuzie & Leech, 2007). Therefore, the participant group of 33 students described above were purposefully sampled to participate in this study (Appendix M outlines all sampling decisions).

Data Collection Instruments

Pretest-posttest. A pretest was administered one week prior to implementation of PBL to assess existing skills related to image critique. The same instrument was administered as a posttest after the students completed the PBL module and delivered their final presentations

(Appendix N). Even though the pretest-posttest instrument included problems to which there were multiple correct answered possibilities, an answer key was established by compiling all possible correct answers provided by ten subject matter experts and a maximum score of 23 points was established. One-half of a point was assigned for each major error students correctly identified on the images provided, as well as for the appropriate corrective action for that error. Additionally, one-half of a point was assigned for each minor error that was correctly identified. The instrument included one image of an axiolateral projection of the hip, Danelius-Miller method, to help assess image critique skills that were specific to this projection, which was used in the PBL module. The maximum score possible for this hip image question was six points.

The instrument was pilot tested by ten radiologic sciences subject matter experts from the researcher's institution to ensure the validity of the instrument. Revisions to the initial instrument were made based on their feedback. Interrater reliability procedures were used to establish the answer key, as well as to score the pretest and posttest. After the instrument was finalized, and administered to the students, another subject matter expert, unaware of the pretest or posttest implementation rounds, scored all of the tests, and calibrated with the researcher. Inter-rater agreement was 90.63% for the pretest and 93.75% for the posttest, while 100% agreement was reached for the hip image pretest and 93.75% for the hip posttest instrument. Internal reliability of the instrument could not be performed due to the question format and inability to code participants' responses.

Surveys. Two surveys (Appendix O) were administered online, before and after the PBL module. The pre-PBL survey, which took about 10 minutes to complete, included six five-point Likert scale items ranging from 1 (*strongly disagree*) to 5 (*strongly agree*), followed by two open-ended items concerning students' perceptions related to group learning. The purpose of this instrument was to capture students' perceptions prior to PBL implementation, related to their preparedness to critique radiographic images, as well as their perceptions related to working in collaboration with their peers. The post-PBL survey included 20 five-point Likert scale items using the same scale, as well as three open-ended items capturing students' perceptions regarding the PBL module and group learning. The post-PBL survey took on average 20 minutes of students' time to complete. The purpose of these two instruments was to compare students' perceptions before and after the PBL in general, as well as to capture their attitudes towards this PBL module.

Structured student reflections. At the conclusion of the PBL module, all students were asked to submit structured reflections that probed their perceptions of the learning experience using PBL. Reflections were analyzed to help answer the second research question.

Data analysis

Pretest-posttest analysis. Pretest scores were compared with the posttest scores using the paired sample (dependent) *t*-test. This test was used to compare the means of two sets of scores for the same participants, in this case scores obtained by students on the pretest and posttest, to determine whether there was a statistically significant difference between these two tests. According to power analysis results conducted using G*Power for the sample size of 33, the effect size of 0.53 was needed to reject the null hypothesis (Faul, Erdfelder, Lang, & Buchner, 2007). However, since only 31 participants had completed the pretest-posttest instrument, effect size needed to reject the null hypothesis for that instrument was recalculated as 0.60 (Faul et al., 2007). Use of null hypothesis tests and consideration of statistical power has questionable utility in the context of a case study, given there was not a conceptualization of some broader population; however, it is instructive to see that a sample size of 33 should be able to detect a standardized mean difference of 0.41 (critical $p = 0.05$, power = 0.80, one-tail, pair sample t-test). This suggests that the within-case sample is large enough for stable estimation of growth in image critique skills.

Surveys. Responses to Likert scale items that were included in the surveys were analyzed descriptively, examining means and standard deviations. Additionally, since the pre- and post-PBL surveys had the four same Likert scale items, those items were matched and compared by using paired sample t-tests, to determine whether there was a statistically significant difference between the means ($p < 0.05$). Open-ended items were analyzed qualitatively by using coding and categorization.

Structured student reflections analysis. Content and thematic analyses were utilized to analyze student reflections using codes and categories. Content analysis was conducted first, as an iterative process that started with a superficial examination of the submitted reflections, reading, and interpretation, as well as organizing information into categories. Furthermore, peer debriefing was utilized by asking a colleague to provide feedback regarding interpretations. Thematic analysis was conducted to recognize patterns and emerging themes within the data (Bowen, 2009), which was compared with the codes and categories generated during the content analysis. This process was further organized through the use of a codebook (Appendix P). The codebook consisted of five parts, including a brief definition, a full definition, specific instances when a code should be used, as well as instances when not to use a code, and finally a section that contains example quotes that demonstrate the code (Guest, Bunce, & Johnson, 2006). The codebook findings were cross-referenced with paired sample t-test results to synthesize qualitative and quantitative findings.

Credibility and Trustworthiness

Qualitative research must promote credibility and trustworthiness, which can be accomplished with strategies used to establish readers' trust (Brantlinger, Jimenez, Klingner, Pugach, & Richardson, 2005). Several credibility measures that were suggested by Brantlinger et al. (2005) were found to be appropriate for this study. First, thick description was recorded to report great detail of information and "enable readers to appreciate and ultimately to derive a deep understanding of the social conditions being studied" (Yin, 2014, p.214). Furthermore, thick description should lead to particularizability, which helps readers "determine the degree of transferability to their own situations" (Brantlinger et al., 2005, p.201).

Data and methodological triangulation were employed through the use of a number of instruments and multiple methods. Peer debriefing was conducted by asking a colleague who was familiar with the context to provide feedback regarding data interpretations and results (Brantlinger et al., 2005). Finally, the researcher practiced reflexivity through consideration of her assumptions and biases at all times, so that she could attempt to understand how those may have influenced data analysis (Yin, 2014). One of the most important biases that may have affected this study, and therefore had to be acknowledged, was that PBL is effective in learning a variety of topics, which stemmed from researcher's personal experiences afforded through her graduate studies.

As previously mentioned, the goal of this study was not to generalize, but to gain understanding of the use of PBL in radiography. Therefore, external validity and generalization were not considered in the design of this research. However, transferability of findings and conclusions was an important consideration. "Transferability is achieved when readers feel as though the story of the research overlaps with their own situation and they intuitively transfer the research to their own action” (Tracy, 2010, p. 845) and can be promoted through the use of strategies, such as thick description (Brantlinger et al., 2005), which has been already discussed.

Delimitation

In order to examine a phenomenon as a case, studies must delimit the case or the object of study (Merriam, 1998) within a specific spatial as well as temporal context (Byrne & Ragin, 2009). This study was delimited to a pre-designed PBL module that was utilized with a group of second-year radiography students at IUN during Fall semester, 2018.

CHAPTER FIVE: RESULTS

Results

The results are reported in this section by research question. The first research question examined the effect of PBL on image critique skills of the radiography students. The second research question examined the students’ perceptions related to this PBL module.

Research Question 1

The first research question was: How does PBL effect image critique skills of second-year radiography students? A paired sample *t*-test was conducted to examine whether using PBL had an effect on the overall image critique skills of the second-year radiography students. Students’ average image critique scores captured by the pretest were 12.52 (SD = 4.51), and the mean score on the post-test was 15.27 (SD = 4.74). The results showed a statistically significant difference between pretest and posttest, suggesting that the PBL module improved overall image critique skills from pre-test to posttest, $t(31) = -5.29$, $p < .05$. The 95% confidence interval for the mean difference between the two time points was -3.81 to -1.69. Effect size estimate, expressed as *d,* was medium ($d = 0.59$) (Cohen, 1988).

A separate paired sample *t*-test was also conducted to examine whether using PBL had an effect on image critique skills related specifically to axiolateral projection of the hip, Danelius-Miller method, as this projection was used to guide this learning experience. Students' average image critique score captured by the pretest was 1.67 (SD = 0.78), and the mean score in the post-test was 3.00 (SD = 1.36). The results showed a statistically significant difference between pretest and posttest scores, suggesting that PBL significantly improved image critique skills related to the hip projection, $t(31) = -7.36$, $p < .05$. The 95% confidence interval for the difference in means ranged from -1.70 to -.96. Effect size estimate, expressed as *d*, was large (d=1.20) (Cohen, 1988).

Research Question 2

The second research question was: What are students' perceptions regarding the use of PBL when learning how to critique radiographic images? To answer this question, responses to the Likert-type items and open-ended items on both the pre- and post-PBL survey are reported. Furthermore, results from the structured reflections designed to probe students' perceptions of their learning experience using PBL were analyzed and reported below.

Likert-type items. The overall mean scores for the six Likert items was 4.08, indicating overall positive ratings above the ‘‘agree’’ level, which was scored at 4.0. The highest rated item on the survey was "Image critique education is relevant to my future practice as a radiographer" (M = 4.88) and the lowest rated item was "I had positive experiences related to learning through group projects in those courses" (M = 3.21).

The overall mean for the 19 post-PBL survey Likert items was 4.10, also indicating generally positive ratings. The highest rated items were "Image critique education is relevant to my future practice as a radiographer" (M = 4.97) and "I contributed meaningfully to the group discussions” (*M* = 4.76). The lowest rated item was “This PBL module enhanced my ability to present in front of people” (*M* = 3.18).

There were four items that were used in both pre- and post-PBL survey. Table 1 presents the pre- and post-PBL survey mean scores, and standard deviations associated with those items.

Table 1

Pre- and Post-PBL Survey Items

	Pre-PBL Survey		Post-PBL Survey	
	M	*SD*	*M*	*SD*
How would you describe your preparedness to critique radiographic images?	3.68	0.60	4.03	0.66
Image critique education is relevant to my future practice as a radiographer.	4.84	0.45	4.97	0.18
The ability to collaborate with my peers is necessary in my future profession.	4.58	0.67	4.71	0.64
Solving problems in a group may be an effective way to practice image critique.	4.06	0.77	4.42	0.76

N = 33

Even though scholars have debated whether Likert data should be analyzed with parametric test such as the *t* test or nonparametric statistics such as Mann-Whitney-Wilcoxon (MWW) test, there is evidence in the literature that these two tests have equivalent power for normal distribution when comparing two independent samples of five-point Likert data (De Winter & Dodou, 2010). Therefore, a paired sample *t*-test was conducted to examine the differences between means on a pre- and post-PBL survey for these four items. For the first item, students rated their preparedness to critique radiographic images before (*M* = 3.68, *SD* = 0.60) and after PBL (*M* = 4.03, *SD* = 0.66). The results indicated a statistically significant difference between pre-PBL survey and post-PBL survey, suggesting that students felt more prepared to critique images, $t(31) = -2.48$, $p < .05$. The 95% confidence interval for the mean difference between the two time points was -0.65 to -0.06. Effect size estimate, expressed as *d*, was medium ($d = 0.56$) (Cohen, 1988). For the second survey item, students rated the relevance of image critique education to their future practice as a radiographer before (*M* = 4.84, *SD* = 0.45) and after PBL (*M* = 4.97, *SD* = 0.18). The results were not statistically significant between pre- and post-PBL survey, suggesting that students' perception related to relevance of image critique did not change as a result of PBL, $t(31) = -1.68$, $p > .05$. The 95% confidence interval for the mean difference between the two time points was -0.29 to 0.30. Effect size estimate, expressed as *d*, was small ($d = 0.38$) (Cohen, 1988). For the third survey item, students rated the importance of their ability to collaborate with their peers in their future profession before (*M* = 4.58, *SD* = 0.67) and after the PBL module (*M* = 4.71, *SD* = 0.64). The results were not statistically significant between pre- and post-PBL survey for this item, suggesting that students' perception related to the importance of their ability to collaborate with their peers did not change after PBL the module, $t(31) = -0.94$, $p > .05$. The 95% confidence interval for the mean difference between the two time points was -0.41 to 0.15. Effect size estimate, expressed as *d*, was small ($d = 0.20$) (Cohen, 1988). For the fourth survey item, students rated solving problems in a group as a way to practice image critique before (*M* = 4.06, *SD* = 0.77) and after PBL (*M* = 4.42, *SD* = 0.76). The results were statistically significant between pre-PBL survey and post-PBL survey, suggesting that students perceived solving problems in a group as a good way to practice critiquing images, $t(31) = -2.01$, $p < .05$. The 95% confidence interval for the mean difference between the two time points was -0.70 to -0.01. Effect size estimate, expressed as d, was small ($d = 0.46$) (Cohen, 1988).

Pre-PBL survey open-ended items. Students were asked to respond to the two open-ended items on the pre-PBL survey. The first item asked students to identify what they liked the most about learning in a group. The most common response identified as a theme was hearing ideas and opinions of their peers (19 students). Similarly, five students identified discussing ideas and brainstorming with others, while four mentioned sharing workload, and two indicated that they liked shared knowledge and different learning styles of their group members. On the other hand, three students could not identify anything that they liked related to learning in a group in the pre-PBL survey.

Students were also asked to identify what they liked least about learning in a group, to capture their perceptions related to group learning before the PBL module. Twenty-one students identified uneven workload as something they disliked, while three students indicated that group work could be distracting and unorganized. Having opposing opinions was also identified as something the students disliked (3 students), as well as having to deliver presentations (2 students), assigning group member roles (2 students), and the time-consuming nature of group work (1 student). One student indicated that there was nothing he or she disliked about learning in a group, while one responded with "n/a."

Post-PBL survey open-ended items. The post-PBL survey included three open-ended items. When asked what they liked the most about this PBL module, the students mentioned the method of learning how to critique images (9 students), knowledge gained, both general (3 students) and topic-specific (3 students), working in a group environment (6 students), and sharing of ideas and opinions (5 students). A couple of students indicated that presentations and learning about the importance of image critique as something they liked the most, while one student responded with “n/a.”

When asked to identify what they liked the least about this PBL module, the most frequent responses were clinical education hours they lost as a result of traveling to campus for weekly group meetings (7 students) and having to critique only one image (7 students). Seven students mentioned group-related issues, such as “my group did not value my opinion at times” and “too many group projects going on, my group is horrible and not getting along,” as something that they disliked. While two students indicated that they were not clear about what was expected of them, other two shared that the learning experience was time consuming, which they did not like. One student wrote that this PBL module did not enhance her or his image critique skills, while one disliked driving to campus. Conversely, two students indicated that they liked everything about PBL.

The third open-ended item asked if this learning module changed students’ attitude toward learning in a group. While nine students indicated that this PBL module affected their attitude toward group learning positively, two students indicated that it had a negative impact on their attitude, and 13 students reported no change in attitude toward working in a group. The students who expressed negative attitudes wrote the following: “Yes, I normally like working in groups, but I did not feel like my group got along well” and “Yes, it made me not like it more.” Similarly, another student indicated that he or she did not like working in groups, but did not explain if that was a result of prior experiences or if it was impacted by this module. Three out of 13 students who indicated that this module did not change their attitude toward group learning did not explain why, while three indicated that their attitude did not change because they like working independently or because of unequal participation associated with group projects. On the other hand, four students explained that this experience did not change their attitude because they have always liked group projects, indicating that they still did after this module. Two students indicated that their attitude changed slightly in favor of group projects, but only because they had a good group. Similarly, another student stated that he or she did not like group projects, but had a great group to work with, resulting in a positive change. On the contrary, two students indicated that they liked group projects, so they could not identify if there was a change in their attitude based on the PBL module experience.

Student reflections. The results in this section are organized by questions that the students were presented with during structured reflections.

What did I learn. Three major themes emerged during the analysis of the structured student reflections related to this question. The first theme was related to learning image critique in general. One of the categories that emerged within this theme was about learning how to be thorough during image critique, as well as learning more about the image critique characteristics. For example, one student wrote the following: “I think that this image critique lab has taught me how to thoroughly evaluate an image” and another one wrote “I learned that you cannot just simply glance at an image and know what is wrong with it, and how to fix it.” Furthermore, one student emphasized the importance of being thorough because “image critique is a complex process that requires good understanding of patient’s positioning, anatomy and pathology,” while another one indicated the following: “I feel better equipped to go back and fix any of my own mistakes and critique myself if necessary.” On the other hand, some students expressed that this PBL module was more of a review of image critique, with answers such as: “the image critique lab was a helpful review of important image critiquing skills. I feel like I needed a refresher course on how to properly critique images, so it really helped me" and "doing this image critique lab felt like almost like a review."

The second theme that emerged was focused on concepts related to the axiolateral hip projection, Danelius-Miller method, as well as critiquing this particular projection. Students wrote that they learned quite a bit about this hip projection. For example, one student wrote: "I learned more about the translateral hip projection and the evaluation criteria that pertains to the projection", while another student wrote:

> this image critique lab not only allowed me to learn more about the cross-table lateral hip, but it allowed me to throughly [sic] critique an image and to truly understand why this image should not have been sent through to the radiologist. I learned many different ways to fix the mistakes that were made when doing a cross-table lateral hip and I can also apply these steps I learned with other exams as well.

The third theme included skills gained that were not directly related to image critique. The first category within this theme included the development of a variety of skills that were utilized in the clinical setting. There were 16 comments that mentioned some of these various skills, including: "I learnd [sic] that my actions and decisions made as a professional have the ability to impact my patients in either a positive or negative way" and "knowledge that goes beyond performing a cross-table hip exam. I learned how important it is to communicate with fellow technologists," as well as

> During this assignment, not only did I learn what to do but also what not to do. I learned to never leave a patient in the middle of the exam. Once you start an exam you should end that exam! I learned not to take over someone else's exam unless you know what is being done. If your name is on the exam, you will be responsible for what follows after.

It was also evident from the students' comments that some may have gained critical thinking skills, as one student indicated the following: "[This lab has taught me] how to critically think about every aspect of that image."

Finally, the fourth theme involved concepts learned that are a result of working in a group. One category included acknowledging differences in how everyone approached image critique. Five answers echoed the following examples: “I learned that everyone’s thinking process can be a little different, but the main goal will always be to obtain a diagnostic exam” and “I learned that while working with groups, everyone processes, learns, and works differently.” Lastly, one student wrote that he or she learned how to work well in a group.

What action will I take? The first theme that emerged from the answers to this question involved actions that were related to image critique. For example, one student indicated the following: “I will take actions to help improve not only my own image critiquing abilities but of those around me who ask my advice.” Additionally, becoming more detail-oriented was outlined as an action. For example, “I will thoroughly view the images before letting the patient go and sending the images to the radiologist” and “after carefully assessing each image, I will have to make a decision on whether or not the image meets diagnostic quality.”

The next theme incorporated various actions pertinent to procedural aspects and patient care. Comments within this category included: “the action to take would have been to go into the patient’s room and verify the positioning and everything else was to your standards because when you take that image, you become responsible for it and the patient,” “I will never make the same mistakes that were made in the video we watched. Each and every patient deserves to be taken care of appropriately,” and “I will take action in making sure to always treat the patient the way I would want to be treated, and to not become sloppy with my future work in becoming an x-ray tech.” Finally, one student highlighted conducting research as an action, stating that he or she would “be able to properly research and provide a solution quicker and with better knowledge” as a result of this module.

What new questions do I have? While five students responded that they did not have any new questions, the rest of the participants' answers were categorized in one of three themes. The first theme focused on questions related to poor image critique skills, including "What causes the technologist to repeat for small errors, and not repeat when there is clearly a huge error that they did not repeat for the day before?" and "I am curious if techs get reprimanded for sending these kinds of images through. I also wonder if techs are re-taught positions that they seem to have forgotten or do not know how to do well," as well as "Why don't technologists critique their images and try to repeat if it doesn't look good?" Similarly, three students asked questions related to poor image quality, including the following: "I sometimes wonder where the line should be drawn when it comes to the patient image quality, radiation exposure and what will be acceptable in the eyes of the radiologist," "how often does poor communication result in an unacceptable image being sent through and how is the patient's diagnosis affected?" and "how would a tech ever allow poor images that could cause a misdiagnosis for the patient be satisfied with their work ethic?"

The second theme involved questions related to the implementation of this PBL module. Three students asked about the scenario presented in the module, such as "if I was the second tech, would I have enough information to take over the exam? What was the technique? How is the patient condition? Will I need help?" Furthermore, one student asked if this module would be implemented in the future, while another asked the following: "Why did we all have the same image to critique and not all have a different image to learn from other presentations on their image critiques?"

Finally, the students brought up questions about the axiolateral hip projection, as well as those related to their ability to transfer skills learned during this module to other exams and situations. Some of the questions included: “I would really like to know why this image is done incorrectly so often,” and “few questions I have range from how should I apply this to other projections?” as well as

> I had questions about more alternative positioning and methods to obtain comparable images if the patient is unable to be positioned correctly. This question led me to refer back to Merrill's and review projections and techniques based on patient condition.

What was the most important thing I learned during this unit? Three major themes emerged from students’ responses to this question. The first theme involved image critique skills and it included two categories. The first category incorporated seven responses related to image critique skills, such as “the most important thing that I learned during this experience is that it is very important to know the proper evaluation criteria” and “the most important thing I learned during this unit, is how to approach an image critique scenario.” Furthermore, one student emphasized skills needed to repeat images and wrote the following: “I definitely learned the importance of every little detail matters and how to fix my own mistakes on the fly and in the long run”. The second category consisted of six responses related to being thorough when critiquing images and included comments such as “it is important to not glance at an image to see if it is good to send to the radiologist, but rather to really look to see if it meets all important evaluation criteria” and “the most important thing I learned during this unit was that you shouldn’t just glance at an image and say, ‘Yeah, that’s fine’.”

The second theme emerged from the responses in which students identified learning a variety of skills related to procedural aspects of radiographic exams as most important, and it included seven responses, such as “the most important thing I learned during this unit is that the issue is not always positioning” and learning “that there is not always one way to do something.” Two of the responses in this theme focused on procedural aspects related to preforming an axiolateral hip examination. For example, a student wrote "the proper ways to position a trans-lateral hip" and another one also wrote that "how to correctly perform this exam, and fix any mistakes I may make in the future" was the most important things they have learned during this module.

The third theme included eight responses related to improved image quality as a result of being more focused on the patient. For example, students wrote that they have learned "that passing an image that does not meet diagnostic quality can lead to misdiagnosis, and could also affect the patient's health," and "to always put the patient first," as well as "to treat patients the way [they] want to be treated."

What parts of this learning experience were the most effective for me? The answers to this question were organized in three themes. The first theme that emerged was learning in a group. Nine students wrote that learning with their peers was the most effective for them. For example, one student wrote that "expanding ideas, knowledge, and critical thinking skills with classmates was an effective way of learning to think outside the box." Furthermore, one student wrote that he or she "learned the most from working in a group, researching together, and questioning each other's ideas," while another wrote the following: "for the way I learn, labs with groups, researching and talking through the projections works best."

Problem-solving approach emerged as the second theme, with nine responses that identified discussions, brainstorming, creating hypothesis and solutions, as well as extra time to spend on the problem afforded by this approach as effective ways of learning in this module. Some examples of student answers in this category included the following: "I think the learning experience that was most effective for me was being able to put everything we've learned from procedures and principles together to come up with our hypotheses and solutions," "I think that the most effective part of this learning experience is being able to talk through the problem with a group and being able to brainstorm ideas of how to fix it," and "it was effective in the way that it made us spend time to really look at the image and to see if it met the evaluation criteria and study how it is supposed to look."

Lastly, the third theme included answers in which students recognized that listening to presentations was an effective way of learning during this module. According to those answers, "listening to everyone else's presentations" and how each group presented a different solution were recognized as effective.

Which of my skills improved during this learning experience? Students' answers to this question resulted in five themes. The first theme emerged from 12 responses, which indicated that students experienced an improvement in critical thinking and problem-solving skills during this learning experience. Nine students described improvement in critical thinking in comments such as: "this exercise improved my critical thinking skills and sharpened my knowledge of relevant anatomy needed for specific exams" and "I think the skills that I generally improved from this lab was my critical thinking skills. Being able to adapt to each situation is what will make the most difference with us as future radiographers." Two answers were focused on skills related to problem-solving, as students wrote that "forming a hypothesis and explaining why as well as a solution to fix it" and "[being] able to go further into solutions" improved as a result of this module. Finally, one student wrote the following: "my problem solving skills improved from this experiment, like I previously mentioned, when performing exams, I think about all the topics I learned in class and put them into consideration for each exam."

The second theme involved image critique skills. Some of the seven responses in this theme identified general image critique skills, as evident in the comments such as "my image critique skills definitely improved during this lab," "I think my image critiquing skills have improved. I'm more willing to stand by a decision to repeat a bad image because I now know how much information could be missing from an unsuitable image," and "I have already paid more attention critiquing all images I take." In addition, one of the responses was focused on hip image critique skills, as the student stated that his or her "skill for critiquing a cross-table lateral hip image, has improved from this learning experience." This student also wrote that this knowledge could be applied in the future to real life scenarios in the clinical setting.

The next theme emerged from three responses, which focused on the improvement of collaboration skills. One of the students provided a detailed description of how working in a group helped improved those skills:

> My group work skills definitely improved during this experience. I was never a fan of group work or group projects, but having a quality team 'pull their weight' and complete the assignments makes a big difference, I was used to always being the person who gets stuck doing everything so it was a nice change to have a proactive group.

Similarly, another student wrote: "This also improved my skills in group projects. Usually I end up doing all the work myself because I do not trust others to get the work done. My group dispersed all of the work evenly and everyone held up their end."

The fourth theme included improvement of communication skills, which were identified in two responses, alongside leadership and critical thinking skills. For example, one student described an improvement in both communication and leadership skills as a result of this learning module.

The final theme focused on the skills related to procedure performance, including "centering correctly, properlly [sic] aligning the tube to the part of interest, proper attire of the patient, and even tech to tech communication,“ as well as "an increase in consistency of quality in my positioning and technical factors, ecspecially [sic] with cross table hips."

What did I learn that surprised me? While five students wrote that nothing that they learned surprised them, their peers responded differently, resulting in four themes that emerged from their answers. In the first theme, eight answers pointed to various aspects of PBL, such as the effectiveness of working in a group and learning from others, as well as how much they liked the PBL process. For example, one student wrote:

> Something that I learned that surprised me is that I would like the problem-based learning technique. At first, I was a little confused on how the whole process was going to work. I liked that we were given a problem and had to solve it using critical thinking skills.

Others wrote answers such as "I didn't think there would be as much to talk about and discuss as there actually was and that each group that presented would touch on a topic or bit of information that no one else had even mentioned" and "I think what surprised me the most was all the different scenarios my classmates presented us with." One of the answers related to working in a group indicated that the biggest surprise was how much the student actually learned from the group members.

Six answers described being surprised by procedural aspects, resulting in another theme. One student identified that it was surprising how "many factors can affect a single image that at first glance only seemed to have a few issues", while another identified positioning errors as an unexpected frequent cause of poor-quality images. Three students focused on the axiolateral hip projection, as they found it surprising that "so many technologists do not understand this projection and how to perform it," despite alternative projections that can result in just as good images, and are easier for the patient.

The third theme incorporated four answers in which students indicated that they were surprised that there were technologists who approve poor-quality images and who frequently "settle for the 'best attempt' with the commonly used projection they are familiar with and proceed to blame their less than perfect images on poor patient conditions." Two of the four students expanded their answers to explain that they did not want to become such type of a technologist. For example, one student wrote "I never want to see myself fall into those poor habits. No matter the exam being performed, patient prep, proper positioning, proper centering, appropriate technique, etc. should be considered."

In the final theme, students emphasized how much they have learned during this module as surprising. There were four responses, three of which were specific to hip image critique, such as "what surprised me during this experience was the knowledge I retained for image critiquing this particular exam" and "what surprised me during this experience was the knowledge I retained for image critiquing this particular exam."

How does this assignment contribute to my growth as a future radiography professional? Five themes emerged from the answers to this last question. The first theme resulted from students' answers that indicated that this PBL module contributed to their growth as a future technologist through improving their skills related to patient care and image quality. Ten responses within this theme included quotes such as "most importantly, I want to be a technologist that produces diagnostic images to the very best of my ability, while giving my patient the best care possible" and

> This exercise will remain with me throughout my career in radiology because it showed exactly the radiographer that I do not want to be. The job can become hectic on any given day with challenges and patient loads can become daunting, but every patient deserves our undivided attention while they are in our care.

The second theme focused on the improvement of image critique skills as a contributing factor to students' growth as a future professional. There were ten comments, including "this lab has positively impacted my future career because it has taught me how to take the proper steps when assessing and correcting an image." Similarly, one student wrote the following: "my overall view of image critiquing has changed, as well as my knowledge of how important it is for the radiologist to be able to make an accurate diagnosis off of my images." One student's answer was more specific as he or she wrote: "this assignment contributed to my growth as a future radiography professional because it improved my image critique skills and it furthered my understanding of the Danielius [sic] Miller projection."

In the third theme, continued effort for professional development was recognized as a contributing factor for the future growth. One student wrote that "it is always useful to continue gaining as much knowledge and education as you can." Six students wrote comments such as the following: "as a future Radiographer I plan to continue to always grow and learn everyday even after I'm finished with school," "working continuously on fine tuning my skills," and "in the future I will challenge myself to think outside the box more with challenging exams, as well as, brush up and utilize specialized exams when necessary or applicable."

In the next theme, students recognized problem-solving and critical thinking as skills that would contribute to their future careers. According to one of the two comments, "this experience showed "how to": collectively problem-solve, use critical thinking, in-depth research, and allocate tasks all within a specific time frame. This will absolutely contribute to my growth as a future radiographer because every day in an imaging department those skills are applied."

Finally, two students wrote that the development of collaboration skills during this assignment would influence their future careers. One student wrote "the group project also ties into working with techs in the future" while recognizing that group projects can be challenging "because not everyone puts in the same effort" and he or she felt that "this is true in the workplace as well." Another student indicated that this learning experience taught him or her to double check everything "that even if you trust another tech, you should still double check everything because what you think is acceptable and what they think is acceptable could be two completely different things."

CHAPTER SIX: DISCUSSION AND CONCLUSION

Discussion

The purpose of this study was to investigate if the PBL module described above had an effect on image critique skills of the second-year radiography students, as well as to capture students' perceptions regarding the use of PBL while learning how to critique radiographic images. This section provides a summary of the study's findings and discussion, its implications, and finally, its limitations.

Summary of the Findings and Discussion

Study's findings are summarized and discussed by each research question. In addition, findings not related directly to either research question were identified and are presented below in a separate section.

Research Question 1. The first research question was: How does PBL effect image critique skills of the second-year radiography students? Image critique can be described as a diagnostic problem-solving process, which requires that students apply critical thinking skills to solve problems at hand (Kowalczyk, 2011). For this study, students' image critique skills were captured before and after the PBL module. Their scores improved significantly between pretest and posttest for overall image critique skills, as well as for image critique skills related specifically to axiolateral projection of the hip, Danelius-Miller method, indicating that PBL is a viable instructional strategy for enhancing students' image critique skills in radiography. Posttest scores were modestly higher than the pretest scores, but the difference was statistically significant, with large effect sizes for overall image critique skills, as well as skills related to critiquing axiolateral hip images. The effect size for overall image critique skills was 0.59, indicating that null hypothesis cannot be rejected, as an *a priori* power analysis indicated that the effect size of 0.60 was needed to do so. Even though gains between pretest and posttest were not large for overall image critique skills and null hypothesis could not be rejected, any gain, no matter how small is important in this context due to its broader implications to possibly improving image critique skills, which have not been intentionally taught in the radiography program. Therefore, additional exposures to similar PBL modules may be needed to witness larger gains in image critique skills.

The effect size for the image critique skills related to the axiolateral hip image was 1.20, indicating a greater difference between pretest and posttest scores than those for overall image critique skills. The difference in effect sizes between overall image critique skills and those related specifically to the hip projection suggested that students learned more about the hip image, which was most likely due to the focus of this PBL module on that particular projection. The learning activities were designed around a PBL scenario based on the axiolateral projection of the hip, which naturally lead students to research and learn further about this specific projection, while learning about image critique in general. Furthermore, one of the soft scaffolds that was provided during this PBL module focused on evaluation criteria related to axiolateral hip images, which most likely helped students develop critique skills specific to this image. In the future, a variety of images may be used during similar PBL modules, if an improvement in overall image critique skills is desired. Providing a variety of images would be beneficial to practicing these skills, as the production of a diagnostic image involves an exponential number of image critique variables that can affect its quality. The possibility of these factors acting upon each other can lead to an astronomical number of possible imaging problems. Therefore, using a number of images would allow students to apply the diagnostic problem-solving process, which requires them to critically think through the greatest number of imaging problems.

These findings related to the first research question are consistent with what previous research related to learning with PBL in nursing education concluded, which is that PBL is effective when critical thinking skills are evaluated (Yuan, H., Kunaviktikul, W., Klunklin, A., & Williams, 2008; Gholami et al., 2016; Tiwari et al., 2006). Furthermore, a meta-analysis conducted to evaluate the effect of problem-based learning in nursing education, which included 22 articles, found a medium-to-large effect size for PBL in nursing education, indicating that PBL offers many benefits to nursing students, when compared with lecture method (Shin & Kim, 2012). Even though the studies included in this meta-analysis were designed to compare pretest and posttest to determine the effectiveness of PBL, similar to this research, most of them had a lecture group and a PBL group, which was not the case in this study. Comparing to studies that only included one group of students was not possible due to lack of such research in the literature that focused on the effectiveness of PBL and used pretest-posttest design.

Furthermore, of greater interest in answering this research question was a comparison of pretest and posttests mean scores, to help understand the connection between PBL use and gains in image critique skills. Even though strong causal inference pertaining to PBL use was problematic given the lack of a control group (Shadish, Cook, & Campbell, 2002), these findings were bolstered via triangulation with the findings from the students' reflection, as well as with students affording strong credit to PBL use. More generally, the purpose of including these data was to yield insights regarding the effectiveness of the PBL processes within radiography instruction and investigate how this student-centered method can fulfill radiography education goals to prepare their students for their future careers. Skills such as effective communication, critical thinking, problem-solving, and desire for lifelong learning are required in the radiography profession and as such are an important part of the radiography curriculum. Typically, most of these skills are taught using lecture-based methods, even though other instructional methods that are learner-centered, such as PBL, may be better suited for their improvement (Kowalczyk, 2011), especially as students do not get the opportunity to practice these career skills when teacher-centered methods are utilized. However, because critical thinking and solving complex problems impact healthcare outcomes and patient care, it is necessary to incorporate them in students' clinical routine (Kowalczyk, 2011; Carvalho et al., 2017; Sangestani & Khatiban, 2012).

Research question 2. The second research question was: What are students' perceptions regarding the use of PBL when learning how to critique radiographic images? Because students' perceptions regarding the use of PBL were investigated before and after the PBL module, findings are presented separately in their respective sections.

Students' perceptions before PBL. In their clinical practice, radiographers are required to make critical decisions about the quality of radiographic images every day (Carlton & Adler, 2013). Therefore, it is not surprising that students' perceptions related to image critique education before PBL were positive, as this was the highest rated item on the pre-PBL survey. Conversely, their perceptions regarding past experiences related to learning through group projects were rather low, as only 36% responded above the agree level. These past experiences may have had a negative impact on students' motivation and willingness to learn with PBL, as they were informed that one of the characteristics of PBL is working in a group. This finding is supported by Levett-Jones (2005), who suggested that pre-nursing students preferred teacher-centered instruction, due to their past educational experiences. Uneven workload, opposing opinions, having to deliver presentations, and the time-consuming nature of group work were identified as characteristics that the students in this study disliked. Students indicated that they liked hearing ideas and opinions of their peers, as well as sharing workload and knowledge. Unfortunately, research studies that focused on nursing students' perceptions related to PBL that were included in the literature review did not investigate students perceptions about group work prior to PBL, and therefore, this finding could not be compared to previous research.

Students' perceptions after PBL. The students perceptions related to the importance of image critique education were still positive after PBL, and were one of the highest rated Likert scale items on the post-PBL survey. While the students wrote that they liked learning how to critique images with PBL and sharing ideas and opinions with their peers, and that they appreciated how much they have learned, when asked to identify what they liked the least, one of the most frequent responses was the loss of clinical education time due to traveling to campus for weekly group meetings. Comments related to missing time at clinical were expected, as students had verbally expressed these concerns at the beginning of this module. Students' dissatisfaction was due to their perception that the time away from clinical education would have a negative impact on their clinical grades, especially as some struggle with the competency-based curriculum, which requires successfully performing a set number of exams every semester. This finding is relevant for planning future implementations of PBL, which would need to be embedded in the clinical education seamlessly in a form of scheduled labs, to avoid this dissatisfaction. In addition, mini PBL modules may be developed to be utilized during downtime when students are not busy with patients, at the clinical locations, so that they would have additional opportunities to practice critiquing images.

Furthermore, the remainder of the comments that indicated limited satisfaction with this PBL module were tied to discomfort with working in a group, which was a repeating theme from the pre-PBL survey comments. Even though it was evident that group dynamics had an impact on students' perceptions, these concerns may dissipate with letting students select their groups on their own (Klegeris & Hurren, 2011), especially when they are in a cohort and have already established relationships with their peers. While students' perceptions toward learning in a group remained the same for 13 students, it is important to note that nine students reported that this PBL module had a positive impact on their attitude, and two reported a negative effect. These findings were in line with what research focused on nursing students' attitudes found. While some found positive perceptions regarding PBL experiences (Rideout et al. 2002; Tiwari et al. 2006), others found that perceptions were opposite, due to adjusting to PBL (Smith & Coleman, 2008). Although difficulties related to transitioning to PBL were not explicitly reported by the students in this study, their comments related to group work indicated that they indeed had trouble adjusting, most likely due to being accustomed to lecture-based instruction. While it may be expected that these difficulties could gradually decrease after more experience with PBL, greater emphasis should be placed on preparing students for this transition, especially when they are new to PBL (Kantar, 2013). Getting students acquainted with the PBL process, as well as offering an ongoing support to address student concerns during PBL delivery has been recommended (Smith & Coleman, 2008). The literature also suggests that students who were inadequately prepared for PBL tend to get frustrated and may not realize the benefits associated with this student-centered method (Levett-Jones, 2005). Even though students in this study were provided with a short introduction to PBL, it may be better to expand that introduction by having them find out about experiences that other students who had completed PBL have shared. Starting with a research assignment in which students learn more about PBL prior to being exposed to it is another strategy that may be utilized to overcome these frustrations. Furthermore, starting with a mini PBL module that is delivered in a single class session prior to modules that are implemented over a longer time period may be a better approach. This particular strategy is documented in the literature and described as the use of "posthole" units (Ertmer & Glazewski, 2015).

Comparison of students' perceptions before and after PBL. Finally, to help determine if there was a change in students' perceptions after the PBL module, a comparison of the four items that were used in both pre- and post-PBL survey was used. When asked to rate their preparedness to critique radiographic images before and after PBL, students reported to feel better prepared after the PBL module. While this may be interpreted as inflated confidence because of higher level of satisfaction with PBL (Rideout et al., 2002), statistically significant difference between pretest and posttest means and the medium effect size in this study indicated that the students were indeed better prepared for image critique after the PBL module. This finding is confirmed with the results from a previous study conducted in nursing education, which compared PBL and lecture-based instruction, and concluded that students who graduated from the PBL program felt well prepared for their clinical practice (Rideout et al., 2002).

On the other hand, the students' perceptions related to relevance of image critique and the importance of their ability to collaborate with their peers did not change after PBL, even though there was an increase in mean scores from pre- to post-PBL survey. The mean scores on the pre-PBL survey related to relevance of image critique and collaboration with peers were well above agree level. This may be due to already established appreciation of these skills, which they frequently see exercised by the radiographers that they work with during their clinical time. Skills related to image critique are key to attaining good patient outcomes, as getting the correct diagnosis in a timely manner is essential to each and every patient. This adds a significant pressure on radiographers, who are tasked with making important clinical decisions based on careful consideration of all factors pertinent to the image appearances, such as anatomy, artifacts, technical factors, and part position, to name a few. The complexity of this task, as well as its impact on the diagnostic process, often require that radiographers collaborate with their peers, which radiography students get to witness regularly, and, as a result, have most likely developed an appreciation for.

Lastly, students perceived solving problems in a group as a good way to practice critiquing images, as evident in their ratings, which were significantly higher on the post-PBL survey. It is promising that students realized the potential benefits PBL might have when practicing image critique, such as sharing of ideas during group discussions, distribution of the workload, as well as the self-directed nature of the learning process. Even though this finding cannot be confirmed with those of other studies, as there is a lack of similar research, this was supported by student comments in the structured reflections. For example, students reported learning more about the image critique characteristics and how to be thorough when critiquing images. They also reported learning concepts as a result of working in a group, indicating that they indeed perceived PBL as a good way to practice image critique. However, the novelty effect needs to be taken into account while interpreting these higher ratings, as it may play a role in students' engagement during the initial implementations of PBL (Hung, 2019). Therefore, offering another PBL module to the same group of students would be useful in identifying if the novelty effect had an impact on their motivation to learn with PBL.

Other Findings. While the purpose of this study was to answer if PBL was effective in improving students' image critique skills, students reported that PBL helped them develop problem-solving skills, as well as communication and collaboration skills, and self-directed skills, as evident in student reflections. Development of these skills is not only consistent with the goals of PBL (Hmelo-Silver, 2004), but is also one of the goals set by radiography curriculum (American Society of Radiologic Technologists, 2017), which follows a pattern designed to train radiography students to become adept in all aspects of performance of diagnostic procedures. Students mentioned that this PBL module contributed to their growth and that they have recognized the value of continued effort for professional development and lifelong learning. These perceptions relate to one of the purposes of PBL, which is to promote responsibility for lifelong learning and continued professional growth (Barrows, 1994). The following quote extracted from a student's reflection is one of the examples that clearly illustrates this perception:

> I plan to put into practice in critiquing my own images and researching what I do not understand as well as what can be applied in daily applications at clinical and beyond. It is always useful to continuing [sic] gaining as much knowledge and education as you can.

Moreover, previous research that implemented PBL in nursing education found that self-directed learning skills and problem-solving were found to be equally developed using either PBL or lecture method (Choi et al., 2014; Gholami et al., 2016; Tiwari et al., 2006). While it seems that development of self-directed learning skills was not exclusive to PBL, it is worth noting that coupled with improved problem-solving, communication, and collaboration skills, PBL may be more advantageous to practicing image critique than lecture method in radiography.

Even though PBL seems to be advantageous in fulfilling radiography education goals, it requires a paradigm shift, for which radiography instructors must be prepared. Mainly, instructors must be ready for a change from the passive transmission of knowledge from instructors to students, associated with traditional lecture-based instructional methods that are prevalent in radiography education (Gosnell, 2010). While the shift from lecture-based methods may be uncomfortable for students, as evident in the findings discussed above, handling a change in classroom dynamics can also be difficult for educators who are new to PBL. For example, the researcher/facilitator in this study found it challenging to continue with PBL and not to switch back to a lecture method in some sessions, on occasions like when students were struggling with moving their learning forward, as evident in her implementation diary. While it was tempting for the researcher/facilitator to share the information students seemed to have needed by adding an impromptu mini-lecture, the researcher/facilitator had to remind herself to continue with the planned PBL module and use facilitation techniques that she prepared for instead. Because of these difficulties, the researcher/facilitator had to make a conscious effort and remind herself of the differences between the teacher-centered method that she has been accustomed to and this new student-centered method, which was not an easy task. Therefore, preparing for challenges that a novice PBL instructor may encounter needs to be a part of planning for PBL, even though it is difficult to anticipate all of the challenges related to a first-time implementation of PBL, especially since the nature of PBL makes it impossible to plan for all possible difficulties, as evident in the adaptations made in this study, as outlined in the researcher/facilitator diary.

Even though any new preparation and addition of the new modules to the existing curriculum can be tedious, the planning process for this PBL module was rather time-consuming for the researcher/facilitator, as it included strategizing about topic selection, developing ways to present the problem in order to better engage the students, preparing resources, developing assessment techniques, and identifying ways to prepare the students for their new roles in the learning process, to name a few. This was not an easy task for this researcher/facilitator, despite her training in PBL and in instructional design, as well as guidance and support she received from expert designers and higher education professionals, one of whom is a PBL expert with many published works related to PBL. In contrast, most radiography educators lack such extensive support and time that is required for planning of PBL, as evident in some of their perceived barriers to adding PBL to their instructional methods. Furthermore, radiography educators identified additional obstacles to using PBL, including lack of resources, being unfamiliar with developing assessment techniques suited to evaluate difficult concepts such as critical thinking, as well as lack of curriculum development skills (Kowalczyk, 2011). While the researcher/facilitator was able to overcome most of those difficulties while planning for this PBL module, due to support she had available to her, she faced other challenges. First, assuming a facilitative role was not an easy transition to make. Even though engaging students and initiating inquiry was not difficult as this was a part of the planning process, sustaining the engagement and ensuring that students stay on track during open discussions was challenging for only one facilitator, given the large size of the class and tutorless groups. However, it is important to note that this PBL module was effective in developing students' image critique skills, despite these difficulties. This is consistent with other research that demonstrated positive results using PBL with large classes without tutors, which was credited to good facilitation skills and addressing certain concerns, such as accountability and workload distribution with tools like peer evaluations in those studies (Klegeris & Hurren, 2011; Woods, 1996). Second, sufficient hard and soft scaffolding had to be provided. Preparing hard scaffolds in advance was a result of detailed planning efforts, especially as quite a few hard scaffolds were found to be necessary in this PBL module. However, delivering soft scaffolds as just-in-time instruction, since they could not be planned for, was more challenging for the researcher/facilitator. In this study, three soft scaffolds were shared during meetings with students, as evident in the researcher/facilitator diary. While it may be useful to compare this to the number of soft scaffolds provided by expert facilitators, it was difficult to find this information in the existing research. Even if such information were available, it would be difficult to compare situations in this PBL module with others, given a variety of contexts, as well as differences in the modules themselves. Lastly, being able to recognize when adaptations are necessary is another important aspect of implementing PBL, which may be difficult to novice PBL facilitators. For example, in this study, revising learning activities, which involved eliminating one of the meetings because students were working ahead, rather than continuing as planned and trying to slow down student progress, was a necessary adaptation in this PBL module, as evident in the researcher/facilitator diary. This finding revealed the importance of allowing for adaptations and adjusting the implementation plan to meet students' needs, as well as improving the plan for future implementations, which has also been recognized in the existing literature (Barab & Luehmann, 2003).

Finally, perhaps the most interesting finding that was identified in this section was the impact that this module had on the actions that students plan to take in the future, as identified in the structured reflections, such as those related to image critique and those pertinent to procedural aspects of radiography exams. The importance of this finding is in the potential impact that this module could have on the quality of care these students will provide to their patients, as procedural and image critique skills directly affect patient outcomes. For example, if a procedure is not performed correctly and the radiographer is unable to identify errors by properly critiquing the image, patient's pathology may be missed due to poor image quality, which may result in a delayed treatment and negatively impact patient safety. In addition, poor image quality can simulate pathology, which, if not discovered by the radiographer, can lead to unnecessary treatments and excessive cost to patient. When errors such as those are discovered, procedures have to be repeated, resulting in doubling of the radiation dose, which is inconsistent with the radiography Code of Ethics to minimize radiation exposure to the patient. Therefore, performing the procedure correctly is of the utmost importance and is considered best practice for the radiography profession. These issues are especially interesting since healthcare organizations and higher education institutions that train healthcare team members have been tasked with improving the quality of patient care and patient safety (Pew Health Professions Commission, 2000).

Implications

This study holds implications that could be useful to radiography educators tasked with planning PBL modules. Allowing enough time for the planning and designing the module with diligence is critical, even though the nature of PBL makes it impossible to plan for all aspects of learning. Choosing an engaging problem that is moderately-structured, relevant, and meaningful to students is important to sustained student involvement, and, therefore, should be taken seriously. Furthermore, educators should strategize how to present the problem to engage students initially. When planning PBL for large classes, letting students self-select groups should be considered, as group dynamics may affect both learning outcomes and student perceptions related to PBL. Allowing students to select their roles in PBL groups according to their strengths may also have an effect on group dynamics. Ensuring that students are prepared for their new roles associated with the PBL approach is also critical to its success. Therefore, educators should start small and design shorter PBL modules that allow students to adjust to the new demands of this student-driven approach before longer modules or curriculum-wide implementation is considered.

Another implication of this study is the PBL module that has been designed and developed for this study being implemented by all the radiography clinical faculty members at the researchers' institution in the Spring semester, 2019. While the new PBL module is very similar to the one used in this study, revisions have been made based on the findings discussed above. The revised PBL module incorporates weekly face-to-face meetings at students' clinical sites, which are conducted during scheduled lab times, as a part of the existing clinical curriculum. These revisions were made to minimize students' dissatisfaction related to their perception that participating in this module caused them to loose time at clinical. Moreover, by having the module implemented at the clinical setting, the instructor-to-student ratio decreased, from 33 students to one instructor, which was the case in the PBL module described in this study, to one clinical instructor having three to five students in their group for the revised PBL module. This revision should eliminate challenges related to a single instructor facilitating large groups of students in the first implementation of PBL, as well as help support sustained engagement and participation, with more frequent student check-ins designed to provide opportunities for students to share what they have learned (Ertmer & Simons, 2005; Ertmer & Glazewski, 2015). Furthermore, the revised PBL module includes using a different image every week, which is an adaptation from the original PBL module, due to the finding that showed the need for a variety of images, instead of focusing on one image for the entire module, with hopes of improving students' overall image critique skills and exposing them to critiquing opportunities with various images. The implementation of the revised module was a much needed change as prior to this, the only opportunity for image critique was when students performed procedures with their instructors, which is not a frequent exercise. Even though clinical radiography instructors, who are delivering this revised module received training focusing on preparing them for their new facilitator roles, they have informally reported that this change is challenging. Overall, the instructors find it difficult to facilitate student discussions instead of providing answers, which is what they have been accustomed to. However, even though the instructors have found this paradigm shift to be challenging, they have also informally shared that they are satisfied with the new module and seem to be eager to add additional ones in other clinical courses, so that students can start practicing image critique skills earlier in the curriculum. In addition, radiography clinical faculty have already discussed starting a shared online library with radiographic images of poor quality to be used for future modules, as well as identifying how to better prepare themselves for PBL by identifying areas that future training should focus on. However, at this point, with this being the first round of diffusion of PBL to clinical radiography instructors, it is important to note that their initial satisfaction may be due to the novelty effect, similar to students' initial satisfaction with PBL discussed above.

Future Research

Future studies that replicate the design of this research could be utilized to validate and extend the findings discussed above. First, replicating this study with a pretest-posttest instrument that has improved psychometric features to better measure learning gains and allow for the procedures to calculate internal consistency would be useful. Addition of assessment tools to capture PBL gains, such as project scoring that evaluates communication or collaboration skills, may also be included. Further improvements may include an addition of a control group, as well as preparing students for their new roles with a short PBL module. As the researcher was also the facilitator of the PBL module, anonymizing student reflections could also be considered, if this study was replicated. Involving another faculty member to implement PBL and collect data is recommended to eliminate potential bias. Additional instructors and tutors could also be involved when studying the effectiveness of PBL with large classes. Specific research that investigates how the use of a variety of images would affect students' overall image critique skills through the comparison of effect sizes would also be valuable. Finally, this study could be replicated in a context other than image critique to add to our understanding of how else PBL can be used in radiography education.

Limitations

This study was conducted with the only cohort that was available in the radiography program at Indiana University Northwest, which limits external validity of this research, as well as internal validity, since there was no control group. Even though the results of this study might not be generalizable to all radiography programs, by describing a phenomenon in great detail, it is expected that the study's conclusions may be transferable to other contexts, times, and situations (Lincoln & Guba, 1985). The concept of transferability deals with the degree to which this can be achieved. While the reader decides if findings are transferable, this cannot be done without detailed description of the context of the study (Brantlinger et al., 2005). Therefore, if transfer occurs, readers may find this study's findings to be relevant to their context, even though that is not the goal of this study. An additional limitation was due to self-reported data that was collected during surveys and reflections, which has a limitation bias that is inherent in self-reporting (Hmelo-Silver, 2004), as well as recall and socially desirable response biases (Tiwari et al., 2006). Researcher bias was also acknowledged as a limitation, especially due to researcher's assumption that PBL is effective in learning a variety of topics, which stemmed from her personal experiences afforded through her graduate studies. In addition, student reflections were submitted to Canvas, and therefore were not anonymous, which may have affected the validity of the data. Completing this assignment was required, but students' responses were not graded, which may have negatively affected response quality. Finally, assessment of PBL was difficult, as recognized in the literature (Savin-Baden, 2004). Measuring complex constructs, such as image critique skills was especially challenging. This difficulty is recognized as a limitation is this study as well, especially because the suitability of the assessment method is unknown, as internal reliability could not be tested.

Conclusion

The nature of image critique makes it challenging, as this skill is acquired with clinical experience and requires extensive knowledge of image critique variables, making it difficult to teach directly. When an image is outside of acceptance limit, multiple solutions and solution paths usually exist, leading to a high number of corrective actions and making the problem-solving process more challenging. Because it is expected that students enter the workforce with this real-world skill, it is essential that they practice this problem-solving process using realistic scenarios, while using skills and knowledge acquired both in clinical and didactic coursework. The purpose of this evaluative case study was to investigate if the use of PBL would have an effect on these important skills in a large undergraduate radiography class at Indiana University Northwest, as well as examine students' perceptions during this learning experience. Conclusions of this study provide a unique insight into the use of PBL in radiography education and could benefit radiography educators and instructional designers who work in similar contexts as described above, by informing them about effectiveness of PBL in large groups of radiography students, similar to the participants involved in this case. Radiography educators and instructional designers are in charge of making design decisions that can impact student achievement, as well as the quality of their learning experience, and as such should rely on evidence-based research results, like those described above. However, it is important to note that additional research that uses assessment appropriate to measuring complex constructs such as image critique skills is necessary before definitive conclusions regarding the use of PBL in radiography can be made.

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Appendix A
Learning Activities

	Goal	Description	Assessment	Participation	Timeline
Step 1	Gain student buy-in	Students view “Introduction to PBL” screencast, which includes PBL definition and background, change in classroom dynamics, student and facilitator roles, and what students can expect from this module.	Reflection	Group, face-to-face	Week 1 (meet for two hours)
Step 2	Initiate student inquiry, establish ground rules and assign student roles (supports first and second STELLAR goal)	Students review Learning Activities (Appendix C). Each group establishes ground rules and selects roles for individual members.	Verbal Report	Group, face-to-face	Week 1
Step 3	Initiate student engagement (supports first STELLAR goal)	Students review radiographic image and the scenario (Appendix B) and record their observations	Reflection; Verbal Report	Group, face-to-face	Week 1
Step 4	Identify learning gaps (supports first and second STELLAR goal)	Students complete KWH part of the chart using a whiteboard (Appendix D).	Verbal Report	Group, face-to-face	Week 1
Step 5	Define task, generate hypothesis, set learning objectives (supports first	As a group, students complete the FILIAP worksheet (Appendix E) to establish a potential hypothesis, an action plan, and distribution of	Verbal report	Group, face-to-face	Week 2 (meet for 2 hours)

	and second STELLAR goal)	workload. Once the chart is completed, students will set learning objectives. Hard scaffolds will be used.			
Step 6	Gather information necessary to solve the problem (supports second STELLAR goal)	Students conduct additional research through IUN Library databases individually, using appendix G; other actions defined in step 5 will also be completed.	Peer- and self-Assessment; Verbal report in Step 7	Individual	The rest of Week 2
Step 7	Revise hypothesis and formulate a solution to the problem (supports first and second STELLAR goal)	Students share and discuss results of their individual research, revise initial hypothesis, as needed, and formulate solution to the problem.	Verbal report	Group, face-to face	Week 3 (meet for 2 hours)
Step 8	Prepare oral presentation (supports second STELLAR goal)	Using the grading rubric and hard scaffolds selected for this step, students create a PowerPoint presentation with a problem solution and corresponding evidence. Students will also prepare for the delivery of their presentation.	Verbal report	Group, face-to-face	Week 4 (meet for 2 hours)
Step 9	Assess content learning and presentation delivery skills	Students deliver group presentations, while the facilitator uses the group presentation grading rubric to evaluate group work. Group discussion and debriefing will be	Group presentation grading rubric	Group, face-to-face	Week 5 (meet for 2 hours)

		facilitated once all presentations are delivered.			
Step 10	Provide opportunity for self-assessment and reflection (supports second STELLAR goal)	Students reflect on the PBL module by completing the structured reflection assignment.	Structured Reflection Assignment	Individual; assignment submitted through Canvas	Due at the end of Week 6
Step 11	Assess individual contributions to group work	Complete peer- and self- assessment.	Peer-assessment	Individual, assessment submitted through Canvas	Due at the end of Week 6

Adapted from Derry et al. (2006)

Appendix B

Hip Image

Appendix C
Video Script

Scene 1: Show the clock on the wall- 6:10 am
Radiographer #1 is in the QC area and she is just checking her phone, relaxing.
Radiographer #2 walks in and says "I just set up two C-arms for my next case with Dr. Peters and snuck out to come hang out. I don't want to be in the room while he is yelling at his nurses for not having this or that ready. I gave Jody my phone number and asked her to call me when he's ready for fluoro. She has done so many spine cases with him, she knows when he will need me."
Radiographer #1 responds: "well, since you are here, I am going to go do my portables. I have a bunch of ICU cases to do, those are such a pain…"
Radiographer #2: "Ok, I will watch the floor for you"
Radiographer #1 leaves.
Scene 2: Show the clock on the wall- 7:25 am
Radiographer #2 is in front of the computer screen. Show the computer screen with the following information:

Jane Smith
Gender: Female
DOB: 2/25/1960
MR: 589686
Exam: Right Hip, 2 view
Indication- Right Hip Pain, SP fall, R/O fracture

Scene 3: Radiographer #2 is pushing the cart into the DR room with Jane on the cart. Jane is in a lot of pain and is complaining. Radiographer #2 is in the room, Jane is on the cart, yelling at her because she is in pain. The scene does not include how Jane is positioned. Radiographer #2 is exiting the room and saying "hold really still, you will be done in just a moment".
Scene 4: Radiographer #2 is setting up at the control panel. Radiographer #1 is walking in: "Hey, I finally finished all my morning portables and could really use a break. I thought I'd never get done"
Radiographer #2's phone rings and she answers it "Ok, I will be there right away". She turns to Radiographer #1 and says "Everything is set up for this hip, just make an exposure, I have to go to surgery right away. Dr. Peters is really upset that I left his OR to come here".
Radiographer #1 makes the exposure and the image comes up as Radiographer #2 is walking away. She looks at the image and says to Radiographer #2 "Hey, what were you trying to do here?" but Radiographer #2 is already gone.
Show the resulting image on the screen.
THE END

Appendix D
Week 1 Handout

Justices say radiology tech should be disciplined

By Steve Korris | Jun 3, 2011

CHARLESTON –- Radiology technician Kenneth Harrison, who injected Benadryl into a patient without a doctor's authority, lost his license for two years.

Post Collimation (Shuttering) Legal Issues, Part 1

In the "legal section" of my presentation I always discussed that at some point I was convinced that someone, somewhere was going to be sued for making a mistake by post collimating pathology off without ever knowing that they had done this. A couple of years ago a very credible radiographer who works in a good size city in the U.S. (with over a million residents and 5+ large hospitals) came up to me and told me the following story. Because of the legal implications I had to promise to keep their name and city a secret, but in a 2-3 year period he/she was privy to 2 "lawsuits" that occurred in their city because of post collimation (shuttering).

October 20, 2008

Supervising Technologists — Radiologists' Liability Issues
By Leonard Berlin, MD, FACR
Radiology Today
Vol. 9 No. 21 P. 28

*Editor's Note: Leonard Berlin, MD, FACR, is a professor of radiology at Rush University Medical College and chairman of the department of radiology at Rush North Shore Medical Center in Skokie, Ill. He began his writing on risk management and malpractice issues in a series of articles in the **American Journal of Roentgenology**. Those articles became the basis for his well-known book, **Malpractice Issues in Radiology**. This Risk Management & Malpractice Defense column is drawn from that book.*

*The third edition of **Malpractice Issues in Radiology** is scheduled for release this fall and will be available from the American Roentgen Ray Society.*

The Case
A 66-year-old man was referred to a hospital radiology department for an air contrast lower gastrointestinal examination because of the recent onset of melena. After completing the fluoroscopic and spot-film portion of the examination, the radiologist instructed the radiology technologist to obtain overhead radiographs of the patient's abdomen with the patient in supine, prone, oblique, and lateral positions. The radiologist also requested that the technologist obtain an anteroposterior view of the abdomen with the patient upright. The radiologist left the fluoroscopy room, and the technologist proceeded to obtain the prescribed radiographs. During this process, the technologist asked the patient if he would be well enough to stand for the upright radiograph, and the patient answered in the affirmative. After positioning the patient against the wall-mounted Bucky grid, the technologist walked to the control panel to make the radiographic exposure. At this point, the patient suddenly collapsed and struck his head on the floor. The technologist quickly summoned assistance, and the patient, unconscious, was placed on a trauma stretcher.

Using Incorrect Algorithms and Look-Up Tables - Legal Issues, Part 2

Blog #23

In September of 2007, I was the Program Director for "Digital Radiography in the 21st Century" which was a 6 hour course presented by Barry Burns – MS, RT(R), DABR now retired adjunct Professor of Radiologic Science, University of North Carolina School of Medicine in Chapel Hill, North Carolina. Barry was a real rarity in the radiology world in that he was both a radiographer and a medical physicist, who had been working with CR since its inception by Fuji in 1983 and until his retirement a few years ago was one of the leading experts in digital radiography in the U.S.

Marking the Image Legal Issues, Part 3

Today I want to discuss markers and marking the image. To make your image a legal document in a court of law, radiation must go through your marker and have it show up and be readable on the image. Please know this has not changed at all with the advent of digital radiography. If you level and window and still can't tell if it's an L or R it doesn't count. If you annotate an L or R it doesn't count. By the way, the marker does not need your initials or the BB's to make it legal, it just needs the L or R.

Medical Malpractice Claims for X-Ray Overexposure

Patients left exposed to x-rays for extended periods of time can be harmed by radiation overdose, and the medical provider may be liable for negligence.

Using Too Much mAs Legal Issues, Part 4

Today I want to discuss the possibility of your facility being sued for using too much mAs (over radiating/over dosing) the patient with CR or DR general radiography. This sort of takes us back to the first blog I ever posted (January 1st, 2013) where I discussed Creeping Dose. The use of too much mAs is certainly still a reality pretty much everywhere, it's just that most of the focus has been on CT and not general radiography. But now that CT doses have been gone over with a magnifying glass, we're next.

To access full articles, see links posted in Canvas in Week 1 Resources

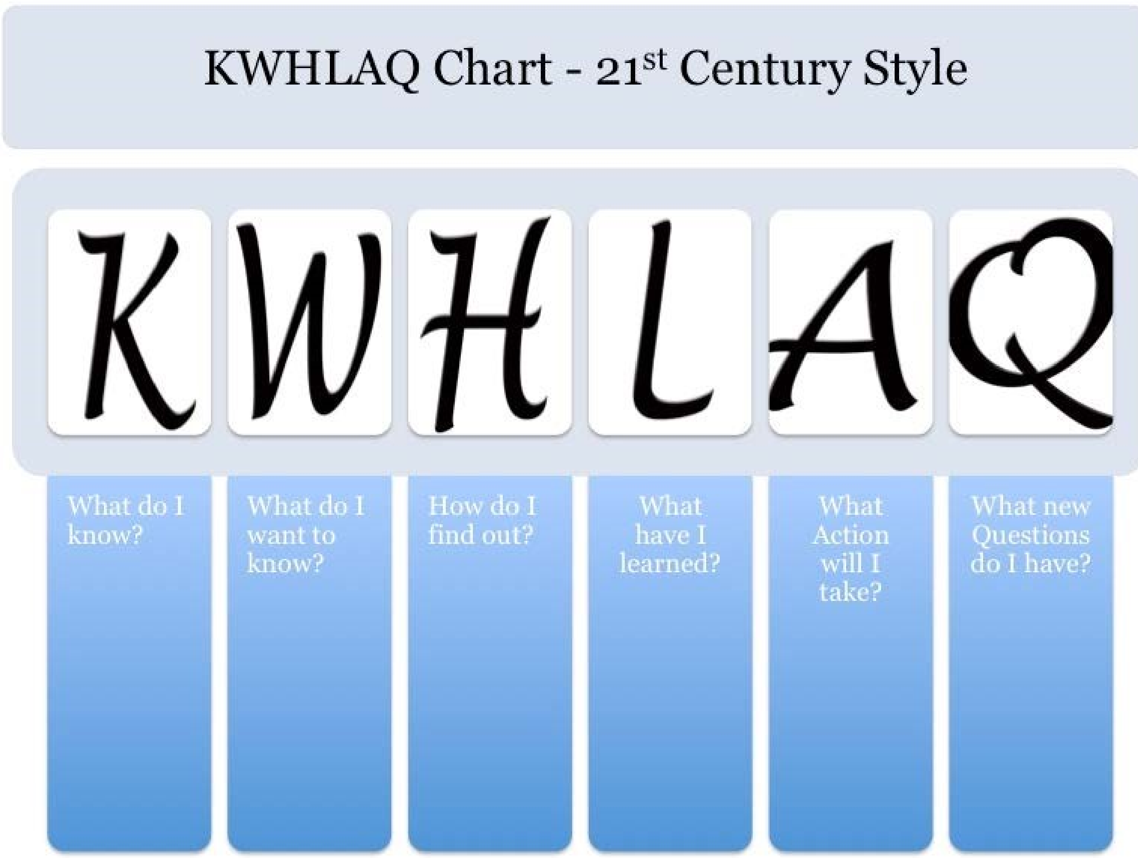
Appendix E

Learning Activities for Students

	Activities	Participation	Assignment
Week 1	• Review "Introduction to PBL" screencast • Consent form • Complete pre-PBL survey • Establish ground rules and select group member roles • Demonstrate how to use whiteboard • Review Day in a Life of a Radiographer • Complete KWH part of the chart using a whiteboard. • Verbal reports	Group, face-to-face	Verbal Report
Week 2	• Complete the FILIAP worksheet • Set learning objectives.	Group, face-to-face	Verbal Report
Week 2-Part 2	• Conduct research through IUN Library databases and other actions as assigned.	Individual	
Week 3	• Discuss research results • Revise initial hypothesis • Formulate solution to the problem.	Group, face-to face	Verbal Report
Week 4	• Create a PowerPoint presentation • Prepare for delivery	Group, face-to-face	Verbal Report
Week 5	• Deliver group presentations • Compare and discuss presentations.	Group, face-to-face	Final Presentations Due
Week 6	• Complete reflection assignment. • Complete peer- and self- assessment	Individual	Reflection, Self-Assessment, and Peer-Assessment

Appendix F

KWHLAQ Chart



Appendix G

FILIAP Worksheet

FACTS	IDEAS	LEARNING ISSUES	ACTION PLAN
Information that is relevant to the problem.	Conclusions regarding the problem (e.g. causes, possible solutions).	List what you need to know or understand in order to solve the problem.	Things that need to be accomplished in order to complete the problem.

Adapted from Hmelo-Silver & Ferrari (1997).

Appendix H

Peer/Self-Assessment Instrument

Please complete this form for each group member as well as yourself. Indicate the student's name and the level of your agreement or disagreement with the statements about that student's performance during all of your group activities by clicking on the appropriate number on the scale.

The student _______________________:

	Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
A. Responsibility and Respect					
1. Completed all assigned task to the appropriate level	1	2	3	4	5
2. Completed all assigned tasks on time	1	2	3	4	5
3. Participated actively in group discussions	1	2	3	4	5
4. Showed behavior that facilitated my learning	1	2	3	4	5
5. Listened to the opinions of others	1	2	3	4	5
6. Showed respect for the opinion of others	1	2	3	4	5
B. Information processing					
7. Brought in new information to share with the group	1	2	3	4	5
8. Provided information that was relevant and helpful	1	2	3	4	5
9. Used a variety of resources to obtain information	1	2	3	4	5
10. Provided reliable resources	1	2	3	4	5
C. Communication					
11. Was able to communicate ideas clearly	1	2	3	4	5
12. Made comments that did not confuse me	1	2	3	4	5
D. Critical Analysis					
13. Gave input that was relevant to the problem	1	2	3	4	5
14. Made conclusions substantiated by evidence	1	2	3	4	5
E. Self-awareness					
15. Accepted criticism	1	2	3	4	5
16. Responded to criticism gracefully	1	2	3	4	5

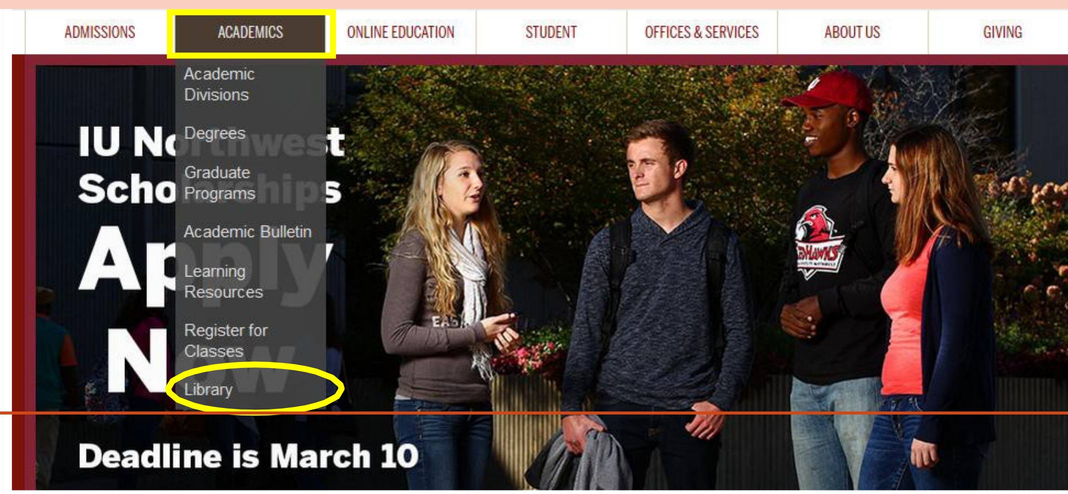
Adapted from Papinczak et al. (2007)

Appendix I

How to Perform a Literature Search Handout

How to Perform a Literature Search

This procedural guide has been designed to assist you in performing a literature search using the IUN library databases. Please follow the steps outlined in the table below using the adjacent screenshots as a visual guide.

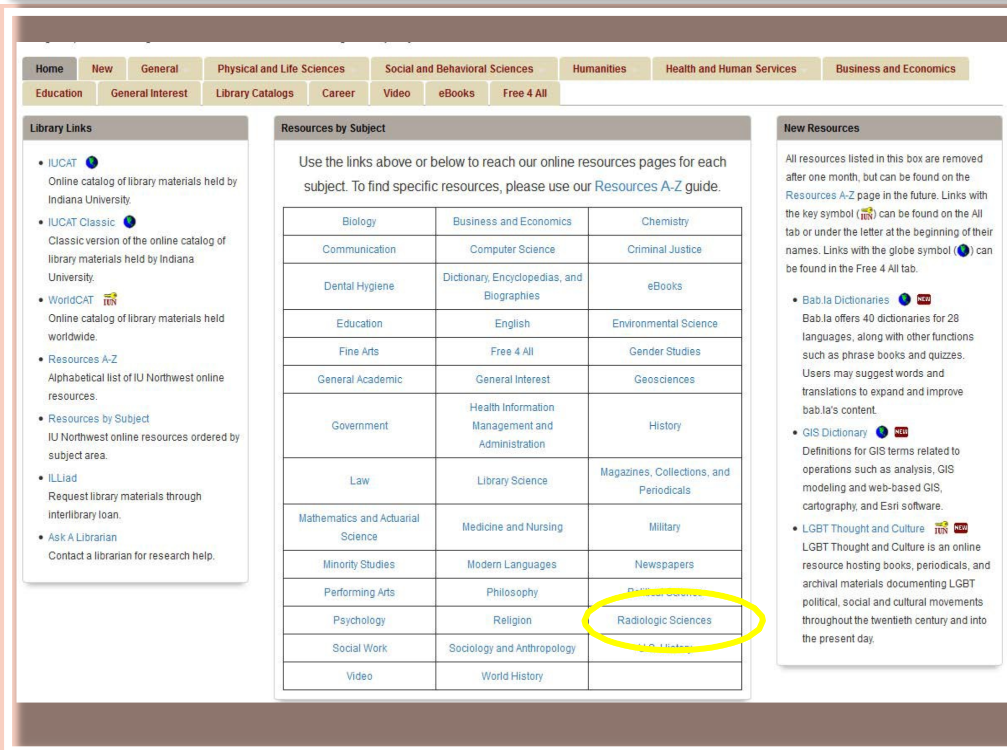
Step	Screenshot
1 Go to IUN homepage Click on ACADEMICS tab Select the LIBRARY link	

2

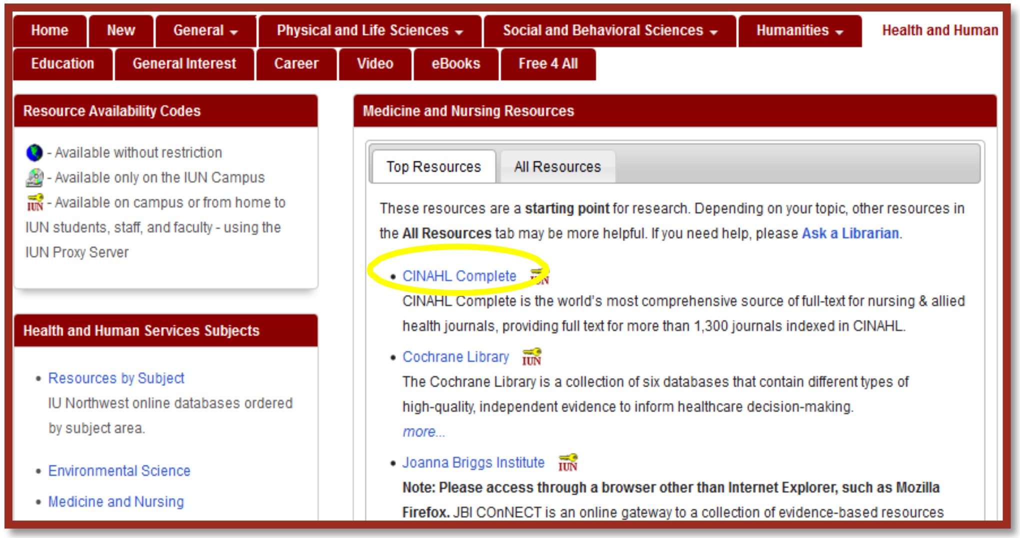
- Go to FIND INFORMATION in the Left corner
- Click on RESOURCES BY SUBJECT

3

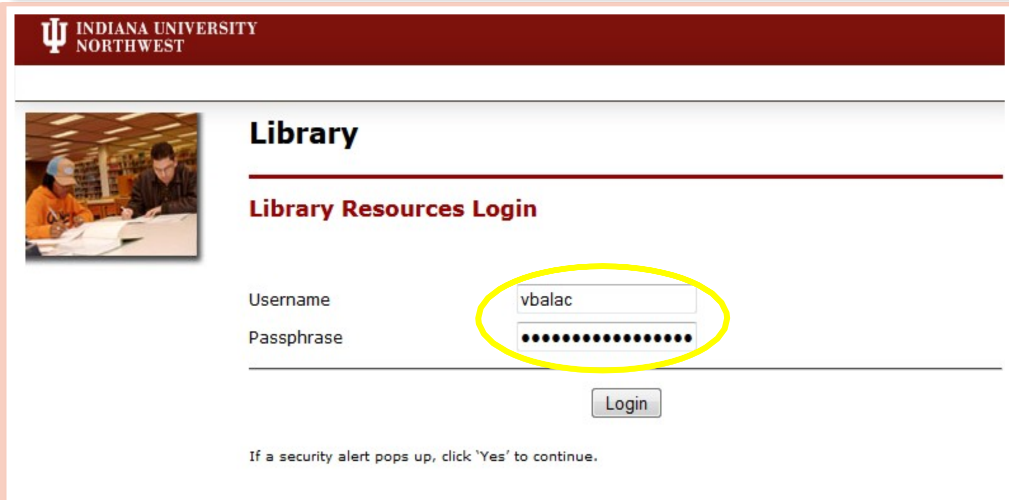
- Click on RADIOLOGIC SCIENCES



4 Click on CINHAL COMPLETE or any other database you are interested in.

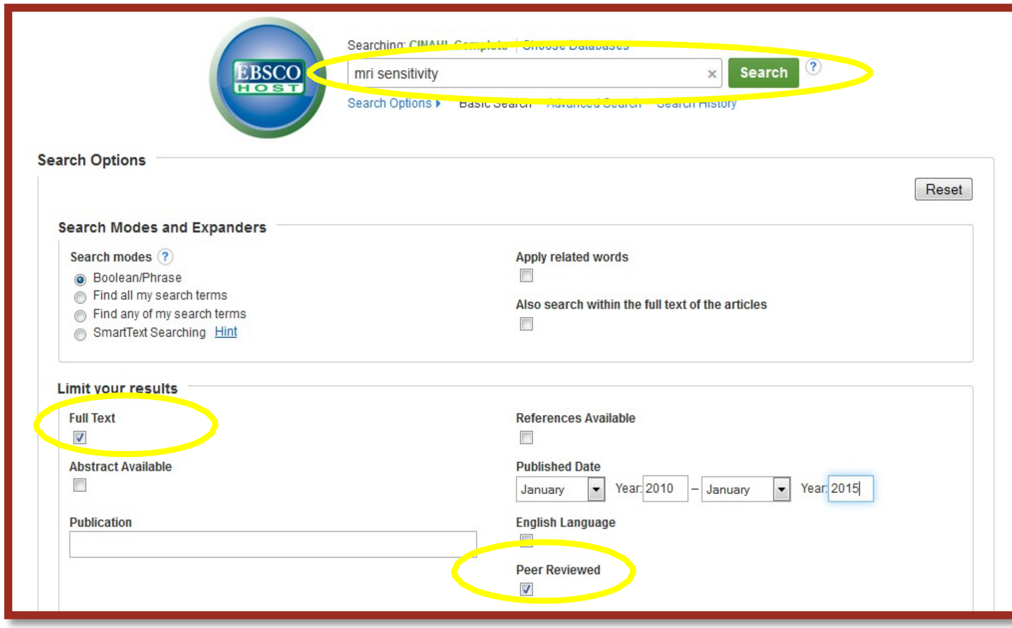


5 Enter your IUN username and password to log in



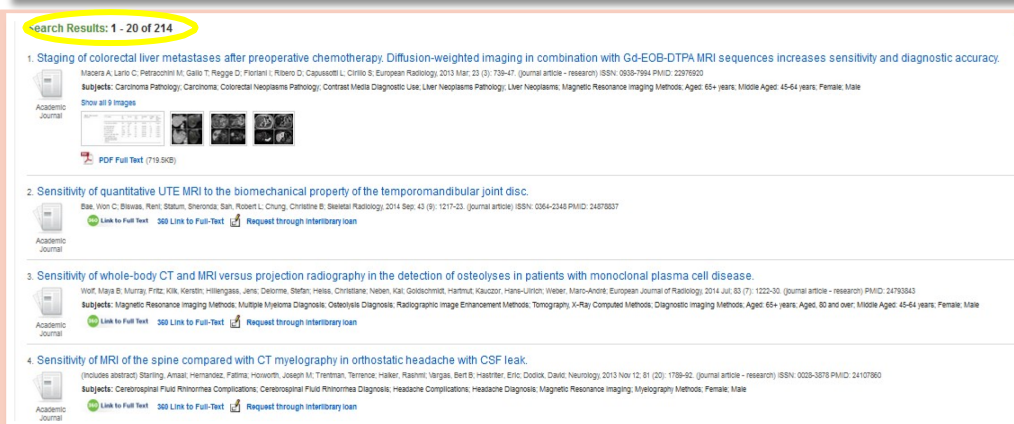
6

- Click on the box under FULL TEXT and PEER REVIEWED
- Type in your topic in the search window and click on SEARCH



7

- Start reviewing your search results



8

You now know how to perform a literature search and find peer-reviewed articles on any topic you choose. Enjoy searching and learning!

References

GoAnimate For Schools. (2014). Make animated videos in the classroom. Retrieved from https://d2qrjeyl4jwu9j.cloudfront.net/static/06cceadbbce7a395/school/img/homepage/img_top_cw.jpg

Appendix J

Group Presentation Grading Rubric

	Unacceptable *(7 points)*	**Acceptable** *(8 points)*	**Good** *(9 points)*	**Excellent** *(10 points)*
Content	The content is inaccurate or overly general. Listeners are unlikely to learn anything or may be misled.	The content is sometimes inaccurate or incomplete. Listeners may learn some isolated facts, but are unlikely to gain new insights.	The content is generally accurate and reasonably complete. Listeners may develop a few insights about the topic.	The content is accurate and comprehensive. Listeners are likely to gain new insights about the topic.
Supporting Evidence	Evidence is not used to support assertions.	Evidence used to support assertions is weak.	Provides some reasonable evidence to support assertions.	Provides convincing evidence to support assertions.
Conclusion	Does not summarize evidence with respect to topic. Does nor discuss the impact of researched material on topic.	Review of key conclusions and some integration with topic. Discusses impact of researched material on topic.	Strong review of key conclusion and some integration with topic. Discusses impact on researched material on topic.	Strong review of key conclusions and integration with topic, Insightful discussion of impact of the researched material.
Organization	Presentation is not organized and lacks focus.	There is some organization, but it lacks focus.	Presentation has a focus and seems to be organized.	Presentation is well organized.

Appendix K

Structured Reflection Assignment

Write a two-page single-spaced reflection paper that answers the following questions:

- *What did I learn?*
- *What action will I take?*
- *What new questions do I have?*
- *What was the most important thing I learned during this unit?*
- *What parts of this learning experience were the most effective for me?*
- *Which of my skills improved during this learning experience?*
- *What did I learn that surprised me?*
- *How does this assignment contribute to my growth as a future radiography professional?*

Appendix L

Researcher/Facilitator Diary

Week 1 Implementation Reflection

Implementation Plan	Implementation Summary
• Review “Introduction to PBL” screencast- 5 minutes • Consent form- 10 minutes • Complete pre-PBL survey- 20 minutes • Establish ground rules and select group member roles- 20 minutes • Demonstrate how to use whiteboard- 5 minutes • Break 10 minutes • Review “Day in a Life of a Radiographer Video”; distribute handout and KWH chart- 5 minutes • NOTE: Project the image on the screen and keep it there for the duration of the meeting • Review the handout and complete KWH part of the chart using a whiteboard- 30 minutes • Verbal reports- 15 minutes	The first part of today’s meeting, prior to the break, did not require any facilitation, due to what was planned. After break, students watched the video and started working on the KWH chart, which required my involvement and I started to utilize some of the facilitation techniques I prepared for. At first, I spent a few minutes with each group, listening to their discussions and then getting involved, as needed. Five of seven groups seemed to be stuck on the procedural aspects and were focused on the scenario in the video. Those groups were repeatedly discussing lack of information, and asking questions which could not be answered, which they felt would be prohibiting them from solving the problem. Some of the group members asked me for additional information and I reminded them that they have to work with the information that was offered to them in the video. Since this was a repeating theme with the majority of the groups, it was very difficult not to jump into lecturing, as this is something I would resort to in the classes I teach. I had to remind myself that this would not be true to the PBL process, so I took a step

	back and thought about facilitation strategies that I prepared for. After some thinking about this situation, it seemed that the students would benefit from jumpstarting. Therefore, I made an announcement to the entire class that the scenario in this video can happened to any of them and that they will need to focus on the information that they have on the image and work through missing information by researching it and finding the solution that would provide the best possible care for their patient. This announcement seemed to be appropriate for the entire class, since only one group was on task and had identified what they already knew and what they wanted to know without much of my involvement. I also utilized redirecting with two of the groups, as I noticed that they were discussing possibilities that could not be determined from the video, from the image, or even through research (e.g. if the patient had a fracture; what brought the patient in to the hospital). Therefore, I asked the students if it was possible to answer those questions and to think about how what they are discussing relates to their goal of solving the problem. After they realized that it did not, I asked them to focus their discussion on the information they have in front of them. Toward the end of this meeting, I recognized the need to provide an additional scaffold at the subsequent meeting because when the students were discussing what they already

	know, it became obvious that they did not have the knowledge needed to critique the image provided. After the meeting, I identified a chapter from an image critique textbook that is not part of our curriculum, but that focuses on evaluating this particular projection. During verbal reports, six out of seven groups identified that they wanted to know how exactly the radiograph was produced and what caused the errors, which is not possible due to the nature of our case. I emphasized that they needed to focus on hypothesizing the cause, as they would not be able to get those answers from the technologist who took the initial image, referring them back to the video. It also seemed that students were struggling with identifying learning gaps this early in the process, which perhaps could be resolved once they start working on the FILIAP chart.

Adaptations:

All went as planned, with the exception of an early finish (10 minutes). Therefore, the only adaptation was shortened meeting time. Furthermore, as a result of this meeting, adaptations for the following week's meeting were planned:

- Start the meeting with a discussion of difference between what the students want to know versus what they need to know and emphasize that what some of the groups identified as "want to know" is not possible to find out in most real world situations, such as our scenario. As a reminder, show the video again to demonstrate why some of the questions students have identified this week cannot be answered.
- Share a new scaffold that explains how to critique axiolateral hip images. The value of this resource is its focus on procedural aspects, so while quite a bit of information is will be provided, students will still need to research how to address technique and other concepts related to principles and pull from what they have learned in some of their didactic courses.

Week 2 Implementation Reflection

Implementation Plan	Implementation Summary
• ADDED: Discuss what students "want to know" and show the video • Distribute and explain the FILIAP sheet. o Instruct students to submit the completed chart in Week 2 discussion thread- (5 minutes) • ADDED: Distribute hard scaffold • Students work on FILIAP chart- 35 minutes • Break-10 minutes- instruct students to meet in the nursing computer lab • Distribute "How to perform a library search" handout and instruct what to do with the research results (save and cite) - 5 minutes • Students focus on performing research identified in the action steps of the FILIAP chart- 40 minutes • Verbal reports- 15 minutes	I monitored discussions and used questioning techniques. During my observations of student group discussion in the first hour of the meeting, it became evident that some students were frustrated. I approached those students to ask them what was going on, to check-in. Most indicated that they did not understand how they would answer their questions and find what they need to know if they could not get information regarding the procedural aspects of the case. It was at this point that I felt tempted to add a mini-lecture to help these groups move forward, but I redirected them to the image instead, reminding them that they should be able to find some of the answers there, and that they would attempt to answer the rest through their research. While this worked for some, it did not for all. Two groups seemed to be stuck in a lower cognitive level and would not let go of the questions they had regarding how the procedure was performed. Therefore, I found that this would be an appropriate time to share the new resource identified after the previous meeting. This seemed to be a necessary scaffold to help students who could not get past the procedural aspects. After this scaffold was distributed, the students seemed to be engaged in applying the evaluation criteria identified in the scaffold to their image, and the ones who seemed to be frustrated no longer appeared to be. I walked around stopping by each group

	for a few minutes, asking questions to promote their discussion. For example, I asked the following: "Based on what you see on the image, can you determine where the central ray was? Could you start there instead of asking me questions about how the procedure was performed?"; "What is it about this image that is still unknown? You need to identify the unknowns and research them." These questions were used to stimulate critical thinking and trigger discussions. I also used revoicing. For example, one group had a discussion regarding the artifact that was on the image and they were guessing what it may be. I repeated all of the possibilities I heard them discuss and asked them to confirm those, but after that, the group indicated that they were not sure if any of those were possible. I asked them what their next step should be. One student answered that they could research them, so I suggested they save that for the second part of the meeting and research it then. I listened to other group discussions and interjected when appropriate. One group indicated that they did not need to research anything, so I asked them to share with me what they had identified on their FILIAP chart. It was clear that their ideas and conclusions regarding the case in the FILIAP chart were not sufficient, resulting in a lack of learning issues. It was evident that this group only focused on procedural aspects and did not address technique and principles of radiograph, which could have been a result of only using the scaffold that addressed procedural aspects of the hip exam. To help this group move forward,

	I pointed them to a soft scaffold that is a more comprehensive resource used for image evaluation. Once we got to the computer lab, I noticed that some groups started working on their presentations. I asked them to stop because that was planned for the following week, but then after watching them proceed with their research, I realized that they were saving the information they found in a Word document, instead of including it in a PowerPoint, which seemed to have added more work. Therefore, it seemed reasonable to leave it up to them and have them start working on the presentation, as using some of the time this week to start the presentation appeared to be a better use of their time. During the remainder of the meeting, it became evident that the students were discussing their research results and working on revising their hypothesis as they were gathering their research results, even though this step was planned for the following week. This seemed like a natural progression and therefore, I did not interrupt the students as they completed this task. This was confirmed during verbal reports when the students reported that their research was completed and hypothesis revised accordingly, and that they only needed to work on creating their presentations.
Adaptations for this week's meeting include the following: • Provided a soft scaffold to help students identify their learning issues other than procedural ones • Students started working on their presentations • Students revised their hypothesis early	

As a result of today's adaptations, the plan for the following week had to be changed and as a result of students being ahead, a possibility of eliminating one meeting became evident.

Week 3 Implementation Reflection

Implementation Plan	Implementation Summary
• Explain Scaffolds related to image critique method/revising hypothesis- (NOTE: this scaffold was distributed in week 2, so this was eliminated) • Explain scaffolds related to presentation (rubric and websites)- 5 minutes • Students work on revising hypothesis first and move on to reviewing resources related to creating a presentation next- 35 minutes • Break-10 minutes • Work on presentations- 50 minutes • Verbal reports- 15 minutes	We started with distributing the hard scaffolds related to the presentation, as the other scaffold that was planned for this week was distributed in the previous meeting. Some of the groups started by revising their hypothesis and I got involved in their discussions and asked them to step back and make sure that their hypothesis aligns with their goal of identifying all errors on the image they had to fix, to be able to produce the best possible repeat of the same image. This reminded students to stay focused on the problem, as a few of the groups were discussing how to make their presentation more interesting and funny and were searching for funny memes instead of focusing on the solution to the problem. I also asked the following: "How did you use the resources I provided today and last week to revise your hypothesis?" to make sure that the scaffolds were indeed utilized.
Adaptations: There were no adaptations made for this week's meeting. However, since the activities that were planned for the following week were conducted this week, the implementation plan will be revised accordingly.	

Week 4 Implementation Reflection

<table>
<tr><th>Implementation Plan (UPDATED)</th><th>Implementation Summary</th></tr>
<tr><td>

Have all presentations on the computer ready to go
Play the video
Decide the order of presentations- 5 minutes
Presentations- 70 minutes
Break while the panel totals the points and selects the winner- 10 minutes
Present the winner with the trophy- 5 minutes
Survey- 10 minutes
Post-test- 20 minutes

</td><td>Students delivered their presentations while the panel (including another didactic instructor and six clinical instructors) scored them using the grading rubric.</td></tr>
<tr><td colspan="2">Adaptation:

Even though having panel members comment on student presentations was not planned, once we presented the winner with the trophy, one of them started to share her thoughts regarding the importance of image critique and the quality of student presentations, so others followed. It was a great way to finalize the face-to-face meetings.</td></tr>
</table>

Week 5 Implementation Reflection

<table>
<tr><th>Implementation Plan (UPDATED)</th><th>Implementation Summary</th></tr>
<tr><td>

Students were instructed to reflect on the PBL module by completing the structured reflection assignment in Canvas
Students were asked to complete peer-

</td><td>Since this week did not include a face-to-face meeting, the only interaction with students was a reminder to complete the reflection and peer- and self-assessment, using Announcements in Canvas.</td></tr>
</table>

and self- assessment in Canvas	
Adaptations: No adaptations were made this week.	

Appendix M

Sampling Table

Participant Type	Sampling Approach	Sample Size	Method	Purpose
Students	Purposeful	33	Pretest-Posttest	To answer research question #1
Students	Purposeful	33	Reflection	To answer research question #2
Students	Purposeful	33	Pre-and Post-PBL Survey	To answer research question #2

Appendix N

Pretest-Posttest Instrument

Image Critique Assessment

Please review the images below and indicate minor and/or major error(s) for each image, as well as corrective measures for each major error.

Terminology:

Major errors are those that the image should be repeated for.

Minor errors are those that do not require repeating an image, but should be corrected if the image is repeated due to major errors.

Corrective measures are steps taken to correct each major error identified

Note: EI values are indicated with each radiograph. The normal range is identified as 200-600, with values that are less than 200 indicating overexposure, and values over 600 indicating underexposure.

Image #1: AP Projection of the Atlas and Axis; Open Mouth

<table>
<tr><td>
EI= 250</td><td>Major Error(s)</td><td>Corrective Measures</td></tr>
<tr><td colspan="3">Minor Error(s):</td></tr>
</table>

Image #2: AP Projection of the Pelvis

<table>
<tr><td>
EI= 123</td><td>Major Error(s)</td><td>Corrective Measures</td></tr>
<tr><td colspan="3">Minor Error(s):</td></tr>
</table>

Image #3: Lateral Projection of the Cervical Spine; Translateral

<table>
<tr><td>
EI= 674</td><td>Major Error(s)</td><td>Corrective Measures</td></tr>
<tr><td colspan="3">Minor Error(s):</td></tr>
</table>

Image #4: Lateral Projection of the Cranium

	Major Error(s)	Corrective Measures
 EI= 614		

Minor Error(s):

Image #5: Parietoorbital Oblique Projection of the Optic Canal and Foramen; Rhese Method

<table>
<tr><td>
EI= 160</td><td>Major Error(s)</td><td>Corrective Measures</td></tr>
<tr><td colspan="3">Minor Error(s):</td></tr>
</table>

Image #6: Axiolateral Projection of the Hip; Danelius-Miller Method

	Major Error(s)	**Corrective Measures**
 EI= 147		

Minor Error(s):

Appendix O

Pre- and Post-PBL Surveys

Image Critique Pre-PBL Survey

By signing the informed consent form, you agreed to participate in this survey. Your participation in this survey is voluntary and you can change your mind and decide not to complete the survey at any time. Deciding not to participate will not result in any penalty and will not affect your relationship with the Radiography Program at Indiana University Northwest. If you feel uncomfortable or you do not want to answer a particular question, you can omit that question and complete the remaining questions. Your responses will be collected anonymously and results will be presented in aggregate form.

If you have any questions, please contact Vesna Balac at 219-980-6540.

Please take the time to read each question/statement carefully and respond with your honest feedback selecting one of the choices below.

1. How would you describe your preparedness to critique radiographic images?
(1 =very inadequate; 2=inadequate; 3=neither adequate nor inadequate; 4=adequate and 5=very adequate)

2. Image critique education is relevant to my future practice as a radiographer.
(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

3. The ability to collaborate with my peers is necessary in my future profession.
(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

4. I have taken college-level courses that incorporated group projects.
(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

5. I had positive experiences related to learning through group projects in those courses.
(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

6. Solving problems in a group may be an effective way to practice image critique.
(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

7. What do you like the most about learning in a group?
8. What do you like the least about learning in a group?

Image Critique Post-PBL Survey

By signing the informed consent form, you agreed to participate in this survey. Your participation in this survey is voluntary and you can change your mind and decide not to complete the survey at any time. Deciding not to participate will not result in any penalty and will not affect your relationship with the Radiography Program at Indiana University Northwest. If you feel uncomfortable or you do not want to answer a particular question, you can omit that question and complete the remaining questions. Your responses will be collected anonymously and results will be presented in aggregate form.

If you have any questions, please contact Vesna Balac at 219-980-6540.

Please take the time to read each question/statement carefully and respond with your honest feedback selecting one of the choices below.

1. How would you describe your preparedness to critique radiographic images AFTER this PBL module?

(1 =very inadequate; 2=inadequate; 3=neither adequate nor inadequate; 4=adequate and 5=very adequate).

2. Image critique education is relevant to my future practice as a radiographer.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

3. This PBL module helped activate my prior knowledge related to image critique.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

4. This PBL module helped me identify areas of weaknesses related to image critique.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

5. This PBL module helped me improve my areas of weaknesses related to image critique.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

6. This PBL module enhanced my ability to present in front of people.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

7. This PBL module helped improve my problem solving skills in general.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

8. This PBL module helped me develop confidence in self-directed learning.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

9. This PBL module was helpful in developing my information synthesizing skills.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

10. This PBL module motivated me to learn more about image critique on my own.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

11. The case used for this PBL module kept me interested in learning how to critique radiographic images.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

12. This PBL module helped me correct my misconceptions related to image critique concepts.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

13. I learned useful information not directly related to image critique during this PBL module.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

14. Group discussions during PBL module helped my understanding of image critique.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

15. The ability to collaborate with my peers is necessary in my future profession.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

16. Solving problems in a group is an effective way to practice image critique.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

17. My group worked well together.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

18. I contributed meaningfully to the group discussions.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

19. I am satisfied with this PBL module.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

20. I would like to learn other concepts using problem-based learning.

(1=strongly disagree, 2=disagree, 3= neither agree or disagree, 4=agree, 5=strongly agree)

Please answer the following questions:

21. What did you like the most about this PBL module?
22. What did you like the least about this PBL module?
23. Did this learning module change your attitude toward learning in a group? Please explain.

Appendix P

Data Analysis Codebook

Code	Short Description	Definition	Use when….	Do not use when…	Example Quote

VESNA BALAC, MS, RT(R)(MR)
vbalac@iun.edu

OBJECTIVE: to provide excellent educational experience to students in radiography and radiologic sciences programs

EXPERIENCE:

2008 – Present Indiana University Northwest, Gary, IN

Program Director Radiologic Sciences
Clinical Assistant Professor/ Clinical Coordinator

Developed online Medical Imaging Technology Program in collaboration with other IU campuses
Designed courses for the online Medical Imaging Technology Program
Developed course materials for a number of face-to-face Radiography and Radiologic Sciences classes
Developed mammography clinical track for Radiologic Sciences students
Redesigned BS course curriculum for compliance with structured educational requirements established by American Association of Radiologic Technologists.
Redesigned course curriculum for Principles of Radiography 3 and Physics Applied to Radiography
Designed assessment tools including examinations and quizzes
Evaluated student performance and learning outcomes
Revised teaching materials and assessment tools yearly to remain up-to-date
Interviewed potential students for radiography program
Participated in a variety of committees on campus and within the department

2007– 2008 Indiana University Northwest, Gary, IN

Guest Lecturer

Lectured for the Advanced Diagnostic Imaging I and Advanced Diagnostic Imaging II

2005– 2011 Community Healthcare System, Munster, IN

MRI Technologist

Performed MRI examinations while ensuring patient safety and compliance with surgical implant safety guidelines
Operated MRI imaging equipment to produce diagnostic images
Assisted radiologists in performing invasive procedures under MRI guidance
Ordered departmental supplies on weekly basis
Served as a member of the Community Healthcare System Outpatient Satisfaction Committee

2004-2005 Community Healthcare System, Munster, IN

Student Extern

Assisted radiologic technologists in performing non-invasive radiologic examinations on patients

Transported patients to and from radiology department while providing basic patient care

EDUCATION:

2019 Indiana University Bloomington, IN

Ed.D. in Instructional Systems Technology

2012 Indiana University Bloomington, IN

M.S. in Adult Education

2006 Indiana University Northwest Gary, IN

B.S. in Radiologic Sciences

Graduated with highest academic honors

2005 Indiana University Northwest Gary, IN

A.S. in Radiography

CERTIFICATIONS:

Registered Radiography Technologist - **RT (R) 2005-present**
Registered MRI Technologist– **RT (R)(MR) 2006-present**

ASSOCIATIONS:
Association of Educators in Imaging and Radiologic Sciences- member in good standing- 2017 to present
Indiana Society of Radiologic Technologists – member in good standing – 2008 to present
American Society of Radiologic Technologists- member in good standing- 2009 to present

AWARDS/HONORS:
2018
Nominated and elected the Vice-President of the Indiana Society of Radiologic Technology
2014
Nominated for the IU Northwest Founders Day Teaching Award
2005
Recognized for outstanding academic achievement and clinical excellence in Radiography

SCHOLARSHIP/CREATIVE ACTIVITIES:
2018
Designed and delivered a five-week long image critique lab using a problem-based learning module.
Revised a nationally recognized textbook:
Carlton, R., Adler, A., & Balac, V. (2019). *Principles of radiographic imaging: An art and a science*. (6th ed.). Boston, MA: Cengage.

Revised an existing chapter in a nationally recognized patient care textbook:
Balac, V. (2018). Radiographic imaging. In A. M. Adler & R. R. Carlton (Eds.), *Introduction to radiologic sciences and patient care* (pp.65-84). St. Louis, MO: Elsevier Saunders.
Designed Professional Assessment of Radiologic Sciences with other Radiologic Sciences faculty members to replace interviews for our programs' applicants

2017

Delivered the first online course for the Medical Imaging Technology Program offered through IUOCC
Designed new projects and online discussions to improve student learning in online courses

2016

Revised most of didactic coursework to improve learning outcomes
Designed two BS courses for online delivery using appropriate instructional theories and micro strategies given online learning conditions
Coordinated a number of **annual** presentations, including communication seminars and patient care labs
Co-presented and coordinated at a cross-cultural simulation that teaches students about cultural diversity
Instrumental in securing clinical excellence plaques and high academic achievement awards for **annual** student graduation

2015

Designed instructional activities that correspond with a visit to an annual conference that involve active learning and peer discussions using LMS
Utilized new assessment tools as a result of attending a two-day Assessment Institute Conference

2014

Revised an existing chapter in a nationally recognized patient care textbook.
Balac, V. (2015). Radiographic imaging. In A. M. Adler & R. R. Carlton (Eds.), *Introduction to radiologic sciences and patient care* (pp.65-84). St. Louis, MO: Elsevier Saunders.
Revised most of didactic coursework to improve learning outcomes
Coordinated a number of annual presentations, including communication seminar, patient care lab, and cultural diversity presentation for AS students
Collaborated with Dr. Ernest Talarico from medical school in planning and organizing the imaging component of the Cadaver Imaging Project of the annual International Human Cadaver Prosection Program
Collaborated with a radiologist and organized annual off-site pathology lectures for BS students to improve learning

2013

Participated in the Cadaver Imaging Project of the annual International Human Cadaver Prosection Program
Presented at the IUSM- Northwest AHEC Program
Attended a presentation about the implementation of new technology used to allow MRI scanning of patients with pacemakers

PROFESSIONAL SERVICE

Campus

2018

Member- Planning and Budget Committee
Member- Faculty Development Committee
Member- Bioethics Steering Committee

2017

Team Leader – FACET Leadership Team
Member- Planning and Budgeting Committee

2106

***Team Leader* –** FACET Leadership Team
Member- Planning and Budgeting Committee
Member- Writing across the Curriculum

2015

Member – Library Committee
Member – Budget Committee

2014

Member – Library Committee

2013

Member – Library Committee
Member – CTDE Committee

2012

***Member* –** Calendar Committee
Member- CTDE Committee

2011

***Member* –**International Affairs Committee
Member - Calendar Committee

2010

Member -Calendar Equipment
Member – Facilities Planning Committee – 2008-2010

2009

Member- Calendar Committee
Member- Equipment Committee

2008

***Member* –** Faculty Organization – **2008-present**

College of Health and Human Service

2018

Participant – Monthly CHHS Directors Meetings

2017

Participant – Monthly CHHS Directors Meetings

2016

Co-chair- Assessment Committee

2015

Member- Assessment Committee

2014

Member – Curriculum Committee
Member – Assessment Committee

2013

Member – Curriculum Committee

2011

Member – Curriculum Committee

2009

Member – AQIP Committee

2008

Participant – Spring Honor's Tea – 2008-2011(program was discontinued)

Department

2017 ***Chair-*** Radiologic Sciences Assessment Committee- 2017- present
Member- Radiologic Sciences Assessment Committee- 2013- 2017
Member – Radiologic Sciences Advisory Committee – **2008- present**
Member- Clinical Subcommittee- **2009- 2017**